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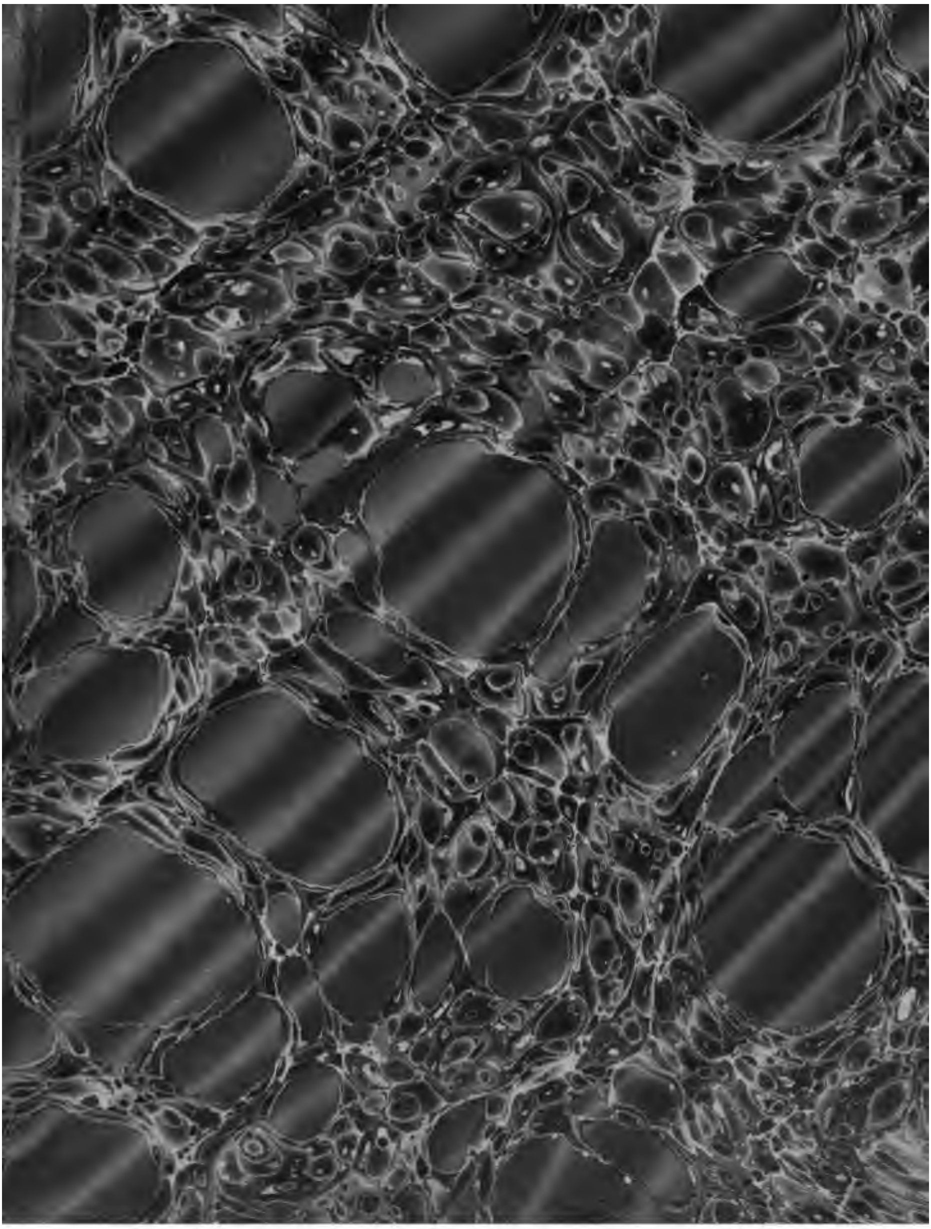

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Royal Geological Society
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OF THE

GEOLOGICAL SOCIETY

OF DUBLIN.

VOL. I.

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DUBLIN:

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1833.

AN ADDRESS

DELIVERED AT THE FIRST ANNUAL MEETING OF THE GEOLOGICAL SOCIETY OF DUBLIN, ON THE 8TH FEBRUARY, 1832. BY THE REV. BARTHOLOMEW LLOYD, D.D. F. T. C. D. PRESIDENT OF THE SOCIETY.

GENTLEMEN—In attempting to address you at this, which is the first General Meeting of the Dublin Geological Society, I feel that the task would have been much better executed by any one of the many individuals around me, whose successful pursuit of the study of Geology would have given more weight to his opinions and recommendations, than I can hope will be attached to any thing I can offer. Indeed, it is a task which I should have declined, were it not one that belongs to the situation in which your kindness has placed me. Something, therefore, must be attempted; and I know not how to discharge my duty better than by adverting to the benefits which have already resulted, and which may be expected, in still greater abundance, to result from the attention bestowed on this department of physical enquiry, and by pointing out the characteristic, and therefore the most attractive features of the country, which we have more especially chosen as the field of our labours.

In adverting to the benefits to be derived from the study of Geology, I would, of course, be understood to speak of it in the state to which it is now advanced, comprising all that has been hitherto ascertained respecting the nature of the materials which constitute the crust of the globe, together with the laws of their distribution and arrangement. Such knowledge, and the multiplied uses for which it is available, are themselves the most satisfactory proofs of the vitality of the

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science, and of the soundness of the principles by which the study is now prosecuted. But these proofs of vitality were not exhibited before the concluding part of the last century. It cannot be denied that the science had been cultivated long before that period, if we should give the name of science to those crude theories, which, being recommended by the ingenuity or the eloquence of the inventors, had successively gained the ascendancy ; each superseding the foregoing, like the waves of the sea, without assisting to advance the bark which carried the fortunes of the human race. There seems no room to apprehend that the science, though still in its infancy, will be confounded with such fruitless speculations ; and I should not have adverted to them, but that they still serve a valuable purpose, that of directing the enquiries of the human mind, by checking its presumption. Impatient of the labour of investigating the laws by which the operations of nature are conducted, the creature of a day has been known to draw on his own ingenuity for the methods by which these things were accomplished ; that is, having satisfied himself as to the mode in which he would have proceeded in this stupendous work, he impiously presumed that this must have been the course adopted by infinite Wisdom. The longer the period during which he continued to philosophise in this way, the stronger becomes the proof of his insufficiency for the task of penetrating the mysteries of creation, without taking for his guidance the indications which had been afforded for his direction ; and that the effort to overcome the difficulties of the subject by the mere force of his own genius was long continued, there can be no doubt ; for if we are asked at what time and by whom the study of the constitution of the earth had commenced, we might travel back from age to age, and find no resting place short of that beyond which we cannot go, the origin of the human race.

But the same Being who had left the creature at liberty to proceed according to his own ways, for the purpose of showing him the extent and the folly of his presumption, has not abandoned him to its consequences, or failed to use with him other more direct methods, both of discipline and instruction. The wonders of creation, expanded before the view, must at all times have engaged the attention of man; and, from the contemplation, he must have derived incalculable advantages for the improvement, not only of his temporal, but also of his spiritual condition. The marks of design and adaptation in the objects of his contemplation were too plain and too numerous to have admitted any doubt as to the existence of an Intelligence infinitely superior to his own; so that in seeking among those objects the supplies of his natural wants, he could not fail to take in a portion of that spiritual sustenance, by which he should become the fit recipient of favors, far exceeding those which merely pertain to his personal accommodation.

Moreover, he would immediately perceive that many of those seemingly spontaneous productions of the earth, which he applied to the relief of his most urgent wants, were brought to maturity by a slow and gradual process, and that this process was favoured by the concurrence of various circumstances; and perceiving this, it would not be enough for him to know to Whom he was indebted for the results so requisite for his support; he would naturally inquire by what means and in what manner, that is, according to what laws and what conditions, these things were effected. When prompted to institute such enquiries, not by a vain curiosity, but by the desire of relieving his wants, or of adding to his enjoyments, he was necessarily restricted to the only proper methods of research. The processes of nature in the production of things requisite for his comfort, must be followed by him who would secure a more ample or a more constant supply; and the properties of bodies must be attentively observed, and the laws and conditions to which they are actually subjected, must be patiently investigated by him who would avail himself of them for the improvement of his condition. Thus, attention to the particular character of the soil most favourable to the growth of certain plants, and of the seasons at which their vital powers are awakened, is the foundation of all artificial cultivation ; and the same attention to the laws of nature is required for the propagation, the growth and domestication of useful animals. In numberless instances, nature thus points out to man the processes to be adopted for securing the most abundant remuneration of his industry and toil ; and great are the advances he must have made under this instruction, even during the earliest periods of his history. In all such cases, being in quest of knowledge applicable to the relief of his physical wants, he was of necessity an humble and pains-taking observer of the laws of nature. He could indulge himself in no fanciful speculations or gratuitous assumptions. Were he to assume that the earth is requisite for plants only as the means of their stability ; and if on this supposition he were to commit the seed to an uncongenial soil, his presumption would soon receive a proper and effectual check ; he would be made to feel the necessity for more self-distrust and a more attentive observation of nature. Should he suppose that the magnetic poles of the earth are those of the axis round which it revolves, he would be led into the most serious errors, in directing his course upon the deep. It was only when the knowledge he sought was not to guide his proceedings, that he ventured to take, what he conceived to be, the shorter road, by following the suggestions of his own fancy, instead of cautiously treading in the steps pointed out by infinite wisdom.

Perhaps the disposition to conclude without sufficient inquiry, at all times too prevalent, may have received some indirect encouragement even from those who, without regarding the theories above alluded to, as certain discoveries or substantial acquisitions, still received them with indulgence as the harmless productions of fancy. It may have seemed to them that where the subject of inquiry did not appear to lead to any immediate results, there was less occasion for that cautious investigation by which men were compelled to grope their way in matters of practical concern; and that the field which seemed to promise little which could be applied to the improvement of man's condition might without detriment, be freely consigned to him for his sportive recreation. But in this there is a great mistake. It is seldom we can assure ourselves, that a discovery of the laws of nature shall not admit of practical application. The instances of such application of philosophical discoveries, never dreamed of by those who made them, are so numerous as to make it altogether unnecessary to go into exemplification. Neither is it true that subserviency to man's bodily wants is the great test of the importance of his discoveries, or of the value of his progress; his mind has also its cravings and its enjoyments; and it is scarcely necessary to insist on the immense disparity between certainty and conjecture with respect to intellectual gratification, or to declare how miserable any substitute which human ingenuity can offer, for the soul-pervading influence of any revealment of the power and wisdom of God in the works of creation.

The folly of substituting idle conjecture for patient research was first successfully shown by the immortal Bacon, by whom also the proper mode of experimental inquiry was pointed out; and from this era, the labours of philosophers being directed into a new course, a harvest of real discoveries was gathered in the space of a single century, surpassing in amount all that had been previously collected since the infancy of the world. The intensity and the laws of those influences by which the movements of the great masses of the universe are controled and regulated, were fully and most satisfactorily ascertained: and their operations having been subsequently traced by the aid of refined analysis, phenomena were brought to light, which were either too minute, or too much mixed up with others, to have been ever discovered but by those who were thus prepared to expect and investigate them.

The discoveries that have been already made of the laws and properties of light, are too numerous to be specified on an occasion such as the present; and the same may be said of those elective affinities, which, by regulating the combinations among the minute particles of matter, constitute the properties of the bodies which we handle and apply to our most familiar uses. In adverting to the brilliant discoveries recently made in these departments, and in those of electricity and magnetism, we must be impressed with the conviction, that we live in an age characterized by an unprecedented rapidity of the progress of the human mind in that knowledge of nature, which, whilst it raises our conceptions of the power and wisdom of God, serves also as our surest guide in applying to our uses the materials of this earth, which He hath formed for the accommodation and subjected to the dominion of man.

But in the study of nature in some of its departments, men still continued to proceed in the old way, heedless of those lights which Bacon had lifted up for their direction. Until very lately, the speculations with which men had indulged their fancies on the structure and formation of the earth, were such as suited the genius of the ancient philosophy; so much, that when we advert to the systems of Burnet, of Buffon, or of Whiston, we might imagine ourselves to live in the age when prismatic colours were dismissed as something unreal, and light itself deemed to be an emanation from the eye.

Fortunately the study of Geology has passed from such visionaries, to those, whose minds, by proper discipline, were better fitted for the pursuit. By the researches of these latter, a considerable number of the most interesting facts in the structure of our planet have been already brought to light, which, when further multiplied, will constitute the proper data from which we are to proceed in speculating on the causes which have brought the world to its present condition, and on the changes which it is destined hereafter to undergo;—in ascertaining the nature of the past or future revolutions of the globe.

I do not maintain that the mass of observations already made is nearly sufficient for this purpose; or that in this, which may be deemed the infancy of the science, hypotheses, which are the only substitute for a perfect theory, are to be decried, as being destitute of all advantage, and productive of nothing but injury. A wide distinction is to be made between hypotheses perfectly gratuitous, such as those before alluded to, and those theories which profess to be founded on facts, though too few for their effective establishment. The former, as causing a diversion from the proper path, were fitted only to perpetuate ignorance. Not so the latter. Professing to be founded on observations, they suggest the necessity of appealing to that test of their truth; and the appeals thus continually made, both by the advocates of such theories and their opponents, are manifestly useful, not *only* in drawing attention to the facts already brought to light, but also in stimulating the industry of those engaged in multiplying the number of such discoveries. Indeed, in this way, hypotheses are our guides in all enlightened investigations: for what we bring to the test of experiment is something which we had previously supposed to be, at least, possible: from partial observation, we form a conjecture as to the mode in which the effect is produced; and this conjecture, proceeding with due caution, we bring to the test of further observation or experiment. When hypotheses are used in this way; when they are founded on observation, and taken as our guides for further investigation, they may and must be admitted into physical inquiries. But for the same reasons for which their use is recommended, they must be deemed prejudicial whenever they are entertained with an assurance disproportionate to the evidence on which they are founded; for then, becoming a substitute for knowledge, they divert the mind from further inquiry. On the whole, I would say, that as in our spiritual concerns, the indications of the will of God are the only sure guide of our conduct, so in our physical researches, the indications of the laws by which He governs the world of matter, are the only clue by which we can hope to advance to their more complete discovery. In truth, the genuine spirit of sound philosophy, no less than that of true religion, is teachableness and humility. As in the one, humility arising from the consciousness of imperfection and weakness is requisite for our real advancement; so also in the other, teachableness of mind, which leads us patiently to trace the operations of Infinite Wisdom, rather than to rely on presumptuous speculations, is the only sure guide to the knowledge of the laws, by which the same Being conducts the operations of his material creation.

For these ends, and in accordance with this spirit, let hypotheses be admitted into geological investigations; and however remote we may be from the time when men shall be enabled to erect a theory of the earth on an immoveable basis, it is to be hoped that observations, as they continue to accumulate, will afford a continually increasing light for speculative inquiry.

The subject is comprehensive, embracing a variety of ends and objects, which to different minds will be differently attractive. But whatever may be the attractions by which any person is directed to the examination of the materials of the earth, their properties and arrangements, it needs not be apprehended that his zeal will be repressed by finding the business uninteresting or uninviting. However introduced, let him but once fairly enter on the subject, and we may predict that he will be more and more quickened to close observation of the formations in the place he inhabits, and even of that through which he travels, and more anxious to procure from others all the information they can impart, respecting the geological condition of those countries to which they may have extended their researches. Neither will he find the work in which he is engaged so separated from other scientific pursuits as to render his other attainments unavailable for his immediate purpose: he will find himself continually called on to borrow lights from various other sources, from mineralogy, from chemistry, from botany, conchology, zoology, and comparative anatomy—I had almost said from every department of natural science; and he may indulge the hope that the time is not distant, when the science of geology shall be so far advanced as to be in a condition to repay the debt it has contracted, by affording light in its turn for the direction of our inquiries in other departments of science. In the mean time it will be, and even now is, in a condition to afford the most valuable assistance, in the conduct of those concerns by which the state of man is supported, or even embellished. The earths are extensively the materials employed in the arts, in medicine, in agriculture, in architecture, in pottery; and a simple recital of the uses to which they have been already applied, would be an almost endless task. Moreover, they are the depositories of the most valuable treasures; and the knowledge of the character of those formations in which particular minerals are imbedded, is of indisputable importance. The experienced geologist, guided by such indications, will pursue his researches with a steady aim, and almost assured prospect of success. I cannot better exemplify this observation, than by stating a fact which came within my own knowledge. In this country, the mountain of Slieve Donard is known to contain beryl; and considerable quantities of this gem had been collected by persons, who never suspected the existence of any other treasure in the same formation: but a specimen of the rock being shown to a distiguished member of this Society, his extensive and accurate acquaintance with the subject enabled him to deliver a decided opinion that topaz would be found in the same rock, and subsequent investigation confirmed the sagacious conjecture.

Furnished with its geological indications, the agriculturist knows to what causes he is to ascribe the good or bad quality of the soil, the knowledge of which is to him as useful as that of nosology to the physician. To both this knowledge is equally requisite in directing them to the mode of treatment: and to the cultivator of the soil, if thus enlightened, the cure is often easy. The material by which it is to be corrected or improved, is frequently to be found in the neighbourhood, and often not far beneath the surface. When the water of a district is too hard for domestic uses, the experienced geologist will readily perceive the cause in the stratum over which it passes, or through which it filters ; and he knows that he can succeed in obtaining a supply of better quality, only by searching beyond the extent of those influences. He knows, that whatever substances it holds in solution, must necessarily diminish its solvent powers with respect to other substances; and as the salts, which it generally takes up in greatest abundance from the earth, are those of magnesia and of lime, it becomes obvious, that to obtain a supply of water such as may be fit for domestic purposes, he is to search for it beyond the limits of the extent of those materials. Thus, the water in the neighbourhood of York is hard, owing to gypsum. The same is true of the well water of Dublin and of London, owing to carbonate of lime. In the latter place, soft water is obtained by penetrating the bed of blue clay, which forms one of the deposits of the great London basin. The stratum of stiff blue clay being mostly of considerable thickness, preserves the water beneath from any intermixture with that above this stratum; and the water beneath, when by the most slender perforation of the London clay it is released from its confinement, mounts to the surface, and in some situations far above it.

Among the most beautiful and interesting discoveries of modern geology, is that of the successive formations which constitute the crust of our planet, distinguished from each other, not only by their characters, chemical, mineralogical, botanical, and zoological, but also by the order of their superimposition, which is inviolably the same in all parts of the world hitherto explored. I have spoken of this order as inviolable; because, though in many places, several of these formations, not only superficial but intermediate, may be wanting, the order is never inverted. It is scarcely necessary to remark on the vast importance of this law, not only as leading to the knowledge of the geological history of our planet, in the various changes it has undergone, but also, which is to us of more immediate and practical importance, in affording an indication of the possible existence of certain strata with their contents, though far beneath the surface; or in furnishing the assurance scarcely less valuable, with which it enables us at once to pronounce, that the search, though carried to the greatest depth, would be utterly hopeless.

From the want of that light, which the knowledge of this law would have afforded, the discovery of the mineral treasures of the earth has been heretofore mostly casual, and the search for such as have not been thus accidentally brought into view, has frequently ended in disappointment, and the ruin of those whose capital was employed in the undertaking. It must, therefore, be admitted, that the knowledge of these indications is of the highest value, not only in preventing the consequence of ignorant adventure, but also in pointing out the circumstances which promise a fair remuneration for the labour and expense of the trial. This observation is particularly applicable to the search after coal, that commodity on which depends the flourishing state of the manufactures in England, and its consequent superiority in this respect, over the other nations of the globe. For the coal-measures being of the medial order among the formations, whose relative positions from the uppermost down to the granite are known, the experienced geologist will find little difficulty in ascertaining by an examination of the surface, whether he is above the coal-measures or beneath them; and in the former case, supposing their existence, whether they be at impracticable depths. The regularity of stratification observable in many parts of Great Britain, affords peculiar facilities for the direction of the adventurer. From the neighbourhood of London, where the surface consists of alluvial deposits, the successive formations rise towards the north-west; and as we proceed from this point in any direction between north and west, the inferior strata are observed successively to crop out; the shortest distances at which they make their appearance, being in the direction of the general rise. Thus the chalk will be found to terminate at Dunstable in Bedfordshire, and never to occur again in any ulterior part of the same road from the metropolis, though we should sink to the greatest depths. Beyond this range of chalk, and even beyond that of the oolite, as far as the red marl and sand-stone, the miner must go to search for coal, if he would propose to find it at a reasonable depth.

This regularity in the dip of the successive formations is not observable in Ireland to the same extent, and in other respects the features of the country assume a character very different. The coast is, for the greater part, lined with primitive rock, frequently rising in bold escarpments, which in many places at no great distance, are backed by lofty mountain groups of the same materials. The central parts, though intersected with mountain ranges running east and west, are comparatively plain, mostly of great fertility, and not uninviting to him who regards them with a view to the advancement of science.

Among the most remarkable features of the surface are its bogs, and the mode of reclaiming these will be among the first of those subjects which demand the attention of the man of science, who would use his skill for the benefit of his country. We know that much has been attempted, and something already done by drainage; but owing to the spongy quality of this material, we know also that drains act to a very inconsiderable extent on either side, and even within these limits but imperfectly, without the use of marl or lime-stone gravel.

The labour of raising this, and still more of carrying it to the spot, and of its proper admixture with the material of the bog, must be great indeed; and if the work be carried to any extent, the cost is enormous; often exceeding the purchase of land of the best quality. But does not the partial success of these proceedings indicate that some noxious principle is to be carried off or neutralized? And is it not worth the trouble of an experiment to ascertain whether the same might not be diluted and carried away by irrigation from a purer source? The experiment might be conducted on a small scale, and in a favourable situation, where a head of water different from that of the bog itself could be obtained; and if successful, there are few situations in which the same course could not be adopted. Almost every where, a supply of pure water, sufficient for the purpose, can be procured and preserved for occasional use by dams or tanks. This was suggested to me in conversation by that eminent geologist, Mr. Smith of Yorkshire, who told me that he had himself practiced it with success, on some boglands on an estate of the Duke of Bedford. For the efficacy of the proceeding he assigned no reason, further than by stating a fact, that the material of the bog was thereby consolidated, and its power of retaining any extraordinary quantity of water thereby destroyed. If the true reason be that which I have taken the liberty of suggesting, it would afford no inconsiderable light for the direction of the experimenter; and though the difference between the marshes, or even the peatlands of England, and the bogs of Ireland, would suggest some doubts as to the success of this method when applied to the latter, it must be admitted, that the bare possibility of succeeding in this way, would warrant a trial by experiment of little trouble or expense.

I should apologize for adverting to a subject which has been often and deeply considered, by those who have united the advantages of scientific skill with that derived from extensive practice, were it not that in this country, the great demand for employment on the one hand, and the vast quantity of waste lands requiring the hand of the labourer on the other, seem to call on every man for any suggestion he can offer, as to the profitable employment of labour in the improvement of the soil.

But to return from this digression. No country is without its overlying formations, whether alluvial, diluvial, or basaltic; and of all these our island will exhibit the most interesting exemplifications. Among these, the foremost to excite attention, and even wonder, is the celebrated formation of columnar basalt, which occurs on the north coast of Antrim; on beholding which, we strain our faculties in our endeavours to form some conception of the power of that agent, whose work thus fills us with astonishment. But we should forbear to speculate too hastily on this subject: for, until experiments are made on the material itself, by subjecting it to the processes we may suppose to have been carried on in nature, our speculations must want the confirmation requisite for the satisfaction of every cautious inquirer. In the mean time, I would remark, that the statement which has been frequently made respecting this formation, namely, that it is confined to that part of the island, and not to be discovered in any other part of the country, is incorrect. Columnar Basalt exists in parts of the island very remote from the Causeway, as in the county of Limerick; and, as I have been credibly informed, in the neighbourhood of Arklow: and as to amorphous basalt, it spreads over nearly the whole of the county of Antrim, and no inconsiderable portion of the county of Derry; and boulders and other detritus of the same material abound in the neighbouring counties of Armagh and Tyrone, and even of Down.

Among the diluvial deposits which seem fitted to command attention, I would regard the Escars, or long but low and narrow hills of water-worn gravel, which occur in such great numbers in some of the western counties. To him who views them in nature, or even on any accurate map, such as that splendid one of the county Mayo, by Mr. Bald, they will suggest the opinion that the surface of the country, at some remote period, had been subject to the action of sweeping currents; and that the fragments of rock which were carried by them and rounded, had been deposited, in these curiously-formed hillocks, where their forces had been checked or exhausted; as the bars are known to be formed at the mouths of rivers, where their force is expended by their mixture with the waters of the sea.

These are not the only features by which this country is distinguished from that of England. Wherever we descend beneath the surface, we perceive a remarkable deficiency of those secondary formations which are there so abundant. I believe a decided chalk formation does not occur in any part of this Island, if we except the white limestone which underlies the great basaltic field of the north-east, and which offers itself to view most remarkably on the coast of Antrim. But there is a marked difference of mineralogical character between this white limestone and the chalk of England; the former being much harder, and containing a greater quantity of imbedded flint.

The same remarkable deficiency is observable as to other formations, such as oolite and red sandstone. Gypsum has been found only in very few places, and consequently rock-salt may be supposed to be very rare. Even secondary limestone, though it unquestionably occurs in many places, is not that which generally abounds on the surface.

But this deficiency of the secondary formations brings us the nearer to those of the middle and lower orders, with their imbedded treasures. Accordingly, on opening the surface, or sinking through the diluvial deposits, the substances which most frequently offer themselves to view, are the granite, slate, mountain limestone or coal.

On the coal-fields of this country, their extent and various qualities, it is unnecessary, and would be presumptuous in me to make any remark; these having been charted and satisfactorily described by one of the most able engineers of which this or any other country can boast.

But coal, though confessedly one of the most extensively useful of all mineral substances, is not the only mineral treasure which has been already brought to light in this country. In many parts are found extensive beds of marble, white, black, and veined, of great variety, and of no mean beauty. Quarries of these have been long time worked, and several others have been recently opened. The same is true also of slate, an article of considerable value when of good quality, and such I believe to be that of this island, of which we have examples in the quarries of Killaloe and Glenpatrick. Beds and veins of the metallic ores may be expected among the primitive formations which constitute so large a portion of the face of the country; and many such have been, and still continue to be worked. Even native gold was found not many years ago in a neighbouring county in large wedges. It was discovered in a limited portion of a stream of about one hundred yards in extent; and though the stream was repeatedly examined up to the mountain from which it descended, not a trace of the metal could be perceived in any other part. Yet, notwithstanding this circumstance, the mountain itself was presumed to be the chief depository: it was accordingly perforated quite through, with great labour and at an enormous expense; and the search conducted in this way, having proved unsuccessful, was finally abandoned. The limited portion of the stream in which any gold could be discovered, we might suppose, should have directed to the adjacent banks, and the hills which rise from the spot on either side. These might have been explored at much less expense; and judging by the uncommonly great size of some of the lumps which had been found, it seems not unreasonable to expect, notwithstanding the past disappointment, that much will hereafter be brought to light.

In fact, the land has exhibited enough of its treasures to assure us that the labour of examination, if directed by science, will be amply rewarded. What has been hitherto found, has been offered to view by accident; and though much of this has been gathered, the country may be said to be as yet unexplored. What science can achieve, remains still to be proved. Of this we are assured, that the field is immense; and that it is marked by characteristic peculiarities to solicit the attention of the scientific enquirer, and awaken his zeal. The English geologist expects from the natives an account of the formations of their country; and can we say that his expectations are unreasonable? And shall we be deaf to the call? Or if we are not to be induced to examine these matters as objects of science, shall we not at least regard them with the interest felt by men desirous of improving the condition of their native land; as the materials placed in our possession by Him who hath assigned to man his task, and who in subjecting the earth to his dominion, hath commanded that it should be cultivated? This command we may be assured, was not confined to the cultivation of its surface: for though, with all the tenderness of an indulgent parent, He hath ordained that the outer mould should afford to man the supply of his first necessaries, He hath assigned to further labour and investigation its abundant reward. Below the surface are treasures, which will amply recompense the labour employed in their discovery, provided that labour is skilfully directed. To furnish the lights and helps requisite for the successful conduct of such enterprise, is one of the main objects for which we are associated. But to be enabled to perform the task with which we have charged ourselves, it is not enough that we should make ourselves acquainted with the outlines of geological science, consisting of those general laws which have been discovered in the arrangement of the materials of the globe, or even with the isolated facts which have been already brought before the view of the public. We must also take this country for our particular study, both as to its general and local characters, and bring our discoveries into the common stock: and for the accumulation of such information, there is no individual who cannot afford some assistance. Each can ascertain the nature of the formations of the district in which he resides, by examination of the places where the surface has been opened, and the materials denuded, as in the beds of streams, in mines and quarries and escarpments; and what he has observed he may record or delineate in drawings or charts. In the prosecution of this work we may hope to receive the most valuable assistance from the able and accomplished gentlemen engaged in the ordnance survey, who have voluntarily added to their other labours, which are considerable, that of making geological maps and collections. When we advert to the skill which they have brought to the task, and the extensive opportunities of observation they have enjoyed, we must feel that our Society has been established at a most auspicious period indeed, and that we begin our labours in the most favourable circumstances.

Let our exertions be worthy of the subject on which we have entered, and of the assistance we shall receive, and it may be safely predicted that the fruits will be acceptable, alike to the patriot and the man of science.

REGULATIONS, &c.

OF THE

GEOLOGICAL SOCIETY OF DUBLIN.

I. OBJECTS.

The Geological Society of Dublin is instituted for the purpose of investigating the mineral structure of the earth, and more particularly of Ireland.

II. CONSTITUTION.

1. The Society consists of Ordinary Members, and Honorary Members.
2. The Officers shall be chosen from among the Ordinary Members, and shall consist of a President, five Vice-Presidents, two Secretaries, and two Treasurers.
3. These, with fifteen other Ordinary Members, shall constitute the Council.
4. The Officers and other Members of the Council for each year shall be elected at the Annual General Meeting of the Society, in February.
5. In case any Officer or Member of the Council resigns or dies, the Council may, if they think necessary, appoint some one to supply his place for the remainder of the year.

III. ADMISSION OF MEMBERS.

1. The sum to be paid by each Member on admission is £2, of which £1 shall be the subscription for the first year.

2. The Annual Subscription is £1, which shall be due on the 1st of January, in each year, and shall be paid in advance.

3. Any Member by Annual Subscription, who shall not pay such subscription within two calendar months after the 1st of January, or within such further time as the Council shall allow, shall cease to be a Member.

4. Any person residing for at least one calendar month in each year, within twenty miles of Dublin, shall be a Member for life, on paying to the Treasurers the sum of £10.

5. Any person not residing for more than one calendar month in each year, within twenty miles of Dublin, shall be a Member for life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5.

6. Any person who shall have become a Member by paying said sum of £5, and who shall afterwards come to reside as above, shall cease to be a Member, unless he shall thenceforward regularly pay the Annual Subscription of £1, or the additional sum of £5.

7. It shall be deemed sufficient service of any notice concerning the business of the Society, to put it into the Post-Office, directed to the residence of each Member.

8. Distinguished persons residing out of Ireland, may be elected Honorary Members of the Society without Annual or other payment, by a vote of the Society at any of its ordinary Meetings, on the previous recommendation of the Council.

IV. OFFICERS.

President.

1. The same person shall not be President for more than two years in succession.

2. The President shall be Chairman of the Council, and of all Meetings of the Society, when present.

Vice-Presidents.

1. Two, at least, of the Vice-Presidents shall go out at each election.

2. The Vice-Presidents shall in rotation or otherwise, as they may agree amongst themselves, supply the place of the President when he is absent.

Secretaries.

It shall be the duty of the Secretaries:—

1. To attend the Meetings of the Society and of the Council, and to see that minutes of the proceedings at each Meeting are entered in a book to be kept for that purpose.
2. At each Meeting to read aloud the Minutes of the preceding Meeting.
3. At the Ordinary Meetings to announce the presents and donations made to the Society since their last Meeting, and to read aloud such original or other letters and papers as the Council shall direct.
4. To conduct the correspondence of the Society.
5. To edite any publications of the Society.
6. To prepare a report of the proceedings of the Society during each year, to be read at the Annual General Meeting.

Treasurers.

1. It shall be the duty of the Treasurers:—
    1. To collect and receive for the Society all Donations and Subscriptions, and enter them in a book.
    2. To furnish an account to the Society, at the Annual General Meeting, of the receipts and expenditure of the preceding year.
    3. To report the state of the Accounts, when called upon by the Council.
2. No money shall be paid by the Treasurers except upon the written order of the Council, at which at least five Members have been present, signed by the Chairman.

V. COUNCIL.

1. Five Members (at least) of the Council must go out at each election.

2. Five Members, including the Chairman, shall be a quorum.

3. The Council shall meet on the first and third Wednesday of each Month. One of the Secretaries, with any two other Members of Council, shall have the power of convening a Meeting of Council at any time.

4. The Chair of the Council shall be taken as that of the Ordinary Meetings.

5. A Member wishing that any of the Regulations of the Society should be altered or added to, must, in the first instance, submit the proposed alteration or addition in writing to the Council. If they approve of it, he may submit it to the Society for discussion at each of the two next Meetings. If it is disapproved of by the Council, he may then submit it to the Society at the Meeting of April or November, provided it is signed by himself and at least ten other Members. On being moved by him or any of these, it may be discussed at each of the two next Meetings.

It may in either case be put to the vote at the last of such Meetings, but not sooner; and if approved of by such vote, it shall form part of the laws of the Society, but not otherwise.

6. It shall be the duty of the Council:—

1. To superintend all the affairs of the Society, and to arrange the times and terms of admission of visitors to the museum and library.
2. To arrange the business to be brought forward at the Ordinary Meetings, and at the Annual General Meeting.
3. To select from the papers and letters communicated to the Society those which appear to them of sufficient interest to be read to the Society, or to be published.
4. To carry into effect, as far as is in their power, the various regulations of the Society.
5. To recommend to the Society the persons whom they

think fit to be the Officers and Council for each ensuing year.

6. To recommend, at the Ordinary Meetings, such persons as they may consider fit to be appointed as salaried Officers, Clerks, or Servants of the Society. But the appointment of such persons shall be made by the Members at the Ordinary Meetings of the Society, by ballot.

7. The Council may exchange or otherwise dispose of duplicate books, maps, or specimens belonging to the Society, as they may deem advantageous to the Society.

8. All the property of the Society to be vested in the Council for the time being, who shall take care to keep accurate inventories and catalogues thereof, which they shall deliver to the succeeding Council, with the property mentioned therein.

9. The Council may authorize the lending of books, maps, drawings, and specimens, to any of the Members, under such regulations and conditions as they may think expedient.

10. All questions at the Meetings of the Council to be decided by a majority of voices.

VI. MEETINGS.

Ordinary Meetings.

1. The Society shall meet on the evenings of the second Wednesday in each Month from November to June inclusive, at the hour of eight o'clock.

2. At the Ordinary Meetings the order of business shall be as follows:—

1. The Minutes of the preceding Meeting shall be read aloud by the Secretary.
2. The donations and presents made to the Society shall be announced and exhibited.
3. Geological communications shall be announced and read.
4. The Members present shall then be invited by the Chairman to deliver aloud from their places, their opinions on

the communications which have been read, and on the specimens and drawings which have been exhibited at that Meeting.

5. When the other business has ended, the Society shall proceed to consider any measures which may be regularly brought forward.

3. The President, or in his absence one of the Vice Presidents or Treasurers, shall be Chairman of the Meeting; and if these shall be absent, the Members present shall appoint some other Member of the Council to preside.

4. All questions shall be decided by the majority of voices.

5. Where the number of voices are equal, the Chairman shall have a casting voice; but he shall not have a previous vote as a Member.

6. Any Member shall have the privilege of introducing one stranger to the Ordinary or Annual Meetings, provided at the time he writes the name of such stranger in a book to be kept for the purpose.

Annual General Meeting.

1. The Annual General Meeting of the Society shall be held on the second Wednesday in February, in each year, for the purpose of electing the Council and Officers for the ensuing year, and hearing the Annual Report of the concerns of the Society.

2. A printed balloting list shall be prepared before the day of the Annual Meeting, containing the names of such persons as the Council shall recommend to be elected Council and Officers for the ensuing year.

3. The Secretaries shall deliver one of such lists to each Member who wishes to ballot, on the day of the Meeting.

4. The Chair shall be taken at two o'clock, P. M.

5. A balloting glass shall be then placed on the table, and remain there for one hour, when the ballot shall close.

6. A Member wishing to remove any person from the list,

may strike out his name, and write in its place the name of the person whom he wishes to be elected.

7. The list shall be thrown into the glass by each Member who votes.

8. The Chairman shall appoint two Scrutineers, whose duty it shall be to superintend the ballot, and see that none but Members ballot—that no Member ballots more than once, or puts more than one list into the glass.

9. At the expiration of the above hour, when the ballot has closed, one of the Scrutineers shall read the several lists aloud, whilst the other shall put a mark against each name as often as it is repeated.

10. The two Scrutineers shall then count the number of marks affixed to each name, and those who have the greatest number of marks shall be elected as they stand in the list, provided that amongst these there be at least five new Members of Council, and two new Vice-Presidents.

11. But if amongst these, there be not at least five new Members of Council, and two new Vice-Presidents, those proposed Members of Council or Vice-Presidents, who have the least number of marks respectively, shall be rejected, until two Vice-Presidents and five Members of Council are excluded; and their places shall be supplied by those who have the next greatest number of marks respectively.

12. If two or more names have an equal number of marks, the order of preference shall be decided by lot.

13. When the Scrutineers have reported those who are elected, the Chairman shall declare the names to the Meeting.

14. Before the commencement of the ballot, the Chairman shall read aloud the preceding regulations.

15. While the ballot is in progress, the Annual Report shall be read aloud by one of the Secretaries; and any Member may propose any question to the Secretaries respecting the matters contained in such Report, and make such observations upon the concerns of the Society as he may think fit.

VII. PAPERS.

1. All papers sent to the Society are to be considered as its property forthwith.

2. No paper shall be read at the Meetings of the Society, until the Secretaries shall have apprised the author of this regulation, in case he shall not be a Member of the Society.

3. If any author shall request that his paper may not be published in the transactions of the Society or otherwise, such request shall be complied with.

OFFICERS OF THE SOCIETY

FOR THE YEAR 1833.

PRESIDENT,

The Provost, T. C. D., M. R. I. A.

VICE-PRESIDENTS,

Richard Griffith, Esq., F. G. S., F. R. S. E., M. R. I. A.
Lord Oxmantown, F. A. S., M. R. I. A.
Colonel Colby, F. R. S., M. R. I. A.

TREASURERS,

Henry Joy, Esq.
Rev. Thomas Luby, F. T. C. D., M. R. I. A.
Sec. to the Dublin Committee of the British Association.

SECRETARIES,

James Apjohn, Esq., M. D., M. R. I. A.
Professor of Chemistry, Royal College of Surgeons.
Rev. Humphrey Lloyd, F. T. C. D., M. R. I. A.
Professor of Natural Philosophy, Trinity College.

COUNCIL.

Francis Barker, Esq. M. D., Professor of Chemistry, T. C. D.
Maziere Brady, Esq. M. R. I. A.
W. R. Hamilton, Esq. F. A. S., M. R. I. A., Astronomer Royal of Ireland.
George A. Hamilton, Esq.
William T. Hamilton, Esq.
Robert Hutton, Esq. F. G. S., M. R. I. A.
Arthur Jacob, Esq. M. D., M. R. I. A.
John M'Donnell, Esq., M. D. M. R. I. A.
Philip Molloy, Esq.
John Nicholson, Esq.
Captain Portlock, F. G. S., M R. I. A.
Richard Purdy, Esq.
H. L. Renny, Esq., R. E.
Rev. George S. Smith, F. T. C. D.
Isaac Weld, Esq., F. G. S., M. R. I. A.

JOURNAL

OF

THE GEOLOGICAL SOCIETY

OF DUBLIN.

ON THE STUDY OF GEOLOGICAL PHENOMENA IN IRELAND.

BY CAPTAIN PORTLOCK, R. E., F. G. S.

(Read April 11, 1832.)

AFTER wandering through all the mazes of conjecture, and trying each tempting path of devious imagination, geology has stopped to inquire seriously, whether the causes now in action are sufficient to have produced the appearances of nature; and to weigh well their influence before she casts into the scale a preponderating mass of speculative hypothesis. This is the only rational mode of searching out truth; for as all human knowledge is built up of fragments, the perfect edifice can only be lasting as the materials first used have been well selected and cemented into a solid foundation. It is, then, this systematic examination, this careful measurement of effects produced before us by existing causes, which distinguishes the geology of the present day, and not the *doctrine* of actual causes itself, for that had long before been broached and advocated; and consequent upon it follows a sober spirit of deduction, not leaping at results, but cautiously trying and securing each forward step. I have ventured on these preliminary remarks; and (although aware that local research and a patient investigation of details are the primary objects of the Society) am about to touch on general topics, because, in the first place, we have formed this happy union at a season when the hammer of the geologist is necessarily idle; and in the next, as it may be useful to point out some objects of inquiry which can be pursued with advantage in Ireland, and thus connect our more obviously useful labours with the higher branches of our science. And I do this the more readily, because I am convinced that the more exalted the object, the more ardent will be the pursuit. The patient watchings of the astronomer are valued by the mariner for some of their practical results; but to himself they are cheered by the splendid glimpses of nature's sublimest works which attend them. So with the geologist—the world will applaud the practical advantages resulting from his inquiries, whilst he himself will be stimulated to toil by the sense of intellectual enjoyment which is always mingled with the more lofty strivings of the mind. He has changed his mode of inquiry, and caution attends his steps; yet is his object still to unravel the mysteries of nature, and if he now has emerged from the vapours of a comet, it is to see more distinctly the surface of the earth itself. He has turned back to the very first page, and owns that he must learn to read before he can hope to understand the book of nature; but still he is progressing, and will never relax his efforts until he has succeeded in spelling and understanding each word, each sentence of its glorious contents. In pursuing the plan I have laid down for myself, I shall endeavour to avoid (as much as possible) mere theorising, though not theory, for that would be to close our eyes against the laws of nature. Without, therefore, any immediate reference to the cause which may have altered the relative levels of the present land and ocean, I shall merely observe, that as the existence far above the waters of the latter of strata full of shells, and other marine organic remains, proves incontestibly that such an alteration has taken place; so having thus recognised the former presence of an ocean rolling its waters over the now dry rocks, we cannot be surprised at tracing its effects in the beds of gravel and sand, or in the pebbles of conglomerates or pudding stones. These latter rocks have, therefore, been considered by geologists as resulting from the destruction of others; and when they occur in horizontal—or if not horizontal, in unconformable stratification on other rocks of inclined strata—they have been deemed to mark the continued though varied operation of disturbing causes such as are supposed to have given an inclination to the beds which support them. View them, indeed, as we will, they show a peculiarity and change of action indicating a geological epoch. In this latter light they are peculiarly deserving of study, nor is it necessary to leave Ireland for that purpose, as they abound in various parts of the island, probably belonging to different stages of the geological series. In the South of Ireland, Mr. Weaver speaks of them as capping many of the higher mountains, and classes them with the old red sandstone. I have myself met conglomerate on the Monavoola mountains in Waterford at the height of 2590* feet; on the Keeper in Tipperary, 2265; and on Bartrigoun in Kerry, 2796; and I may add, on Mr. Weaver's authority, Galtymore, 3000. Here, then, we find a rock of aggregated or mechanical structure, resting nearly horizontally on some of the highest hills of the country, and a subject for minute inquiry and careful examination at once opens to our view. Considering such rocks as resulting from the destruction of others, and noticing their present elevated situations, we naturally look around for more elevated ridges which might have supplied the materials of which they are formed, when we find few hills exceeding them in height, and none of sufficient extent (in their actual state) to have furnished the necessary quantity of detritus. Nor can we discover in the higher hills, or even in those of which the conglomerate now forms the upper part, all the substances which it contains; for instance, the material of the large nodules of coarse red jasper which are so abundant on Bartrigoun, and which have not (to my knowledge) been traced to a parent rock in this country: a similar difficulty having been met with in others where they have also occurred—such, for instance, as the nodules of red quartziferous porphyry in the Exeter red conglomerate.† This form of the conglomerate, too, is not general, as the red nodules are not present in all its Irish localities. Yet even where *they* are absent, it is still difficult to conceive whence so many pebbles of pure quartz, such as those of the Keeper, could have been derived, unless, indeed, from the destruction of extensive veins, which would imply the still more extensive destruction of the rocks containing them. Again, comparing these conglomerates at various points, that of the Keeper is superficial, that of Bartrigoun of great thickness. The former, too, is of a closer texture, more firmly cemented, and at once more uniform in structure and less complex in its ingredients. These differences lead me to ask whether the geological position of the rocks in question has been fully established—whether they have been identified with each other, and whether the connection of each or either has been satisfactorily made out with the rocks next in succession, such as those of the great limestone tract of the country below? To me it does not appear that they have; and I would urge those geologists who, during their summer researches, may visit the districts referred to, to take sections through these highly interesting mountain chains, bringing them down to the plains on each side, and carefully observing the points of contact of the conglomerate with other rocks. Some such I hope to take myself, but the more they are multiplied the better; and I will venture to say, they will explain more clearly the relation of the several rocks to each other than any hasty examination of the level country could possibly do; and, at the same time, elucidate what now appears a very curious state of circumstances. Nor is it to this peculiar case that the necessity of carefully determining the heights above the ocean at which each rock or stratum appears, alone applies. It is equally useful and necessary to do so in all; and whoever looks at the intricacy of surface which characterises so many mountain chains must at once see that the height is often his only, or at least his chief guide in tracing the continuation of a stratum. Playfair recommends such determinations; and in repeating his recommendation, I am happy to say, that the present survey of Ireland will give the summit heights of every hill in the country. Nor need we wait its conclusion, as I am sure its conductor, Colonel Colby, will readily supply to any geologist wishing to examine a mountain district such heights as have been already computed, and with them the intermediate determinations, whether effected by barometers or by levelling, may be compared, and their accuracy checked and secured.

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* The height of Monavoola.

† M. De la Beche's words might indeed be mine, when he says, "The presence of these porphyries in the red conglomerate of S. Devon, where they are abundant, is somewhat remarkable, for they have not yet been traced to their parent rocks."

Let me now recapitulate those heads of inquiry which I have suggested in connection with the conglomerate rocks. 1st.—Are the conglomerates which cap so many of the highest hills in the South of Ireland all parts of the same stratum, or is there a difference in their respective ages. 2d.—Can they be actually traced to underlie the limestones; or if we consider, with Mr. Weaver, that there is a division of these limestones, part being associated with the greywacke and part with the ordinary carboniferous series, can we trace these to overlie one portion and to underlie another. And 3d.—If we cannot actually find them overlying or underlying the limestone, but on the contrary ending abruptly on the sides of the mountains, can we discover any facts which will enable us to judge whether these distinct mountain summits (the distance between Bartrigoun and the Keeper being seventy-six miles, and that between Bartrigoun and Monavoola ninety-two miles) are the remnants of a once continuous coating now worn away, or have been lifted up with the more ancient rocks beneath them, and thus placed at a higher level than the great mass of limestone supposed geologically to be in order above them. By pursuing these investigations we shall probably combine together the disjointed portions of the geology of the South of Ireland, and by extending them to the other parts of the island, we may possibly even find marks of some of those operations of nature which are now studied with so much effect in other countries. We may, perhaps, extend the dominion of the earthquake over the surface of our island, discover the direction of its impulses, and estimate the varying intensity of its successive oscillations. But to success in such a research the mode of minute inquiry here suggested is essential; for our mountain chains are not, as those of other regions, sufficiently prominent to mark by their direction alone that of the forces which have acted upon them.

The next subject I would place before the Society is the degradation or wearing down of the surface of the earth by atmospheric agents, which is indeed every where and every instant so palpable that nothing but familiarity makes us overlook it. Illustrative instances might in truth be found in the pavements of our streets, the steps of our doors when exposed to drip from the roof, and the piers of our bridges. And I will add one highly illustrative artificial example which I find in a note to the first number of the "Journal de Geologie." Mr. Bouè there observes, that the marble of Salzbourg is formed into small cubical morsels, which being put into barrels with water, and then by rapid turning caused to rub, just as pebbles in a stream, against each other, are reduced to a spherical form, such as we see in the playing marbles of children. That the effect of such an action long continued must be exceedingly great, who would doubt? and yet we may well hesitate to ascribe to it, as some do, the entire hollowing out of valleys; for were we so to reason, a difficulty would meet us in this, that in many cases we should ascribe the same apparent amount of wearing to the same cause, though the rocks acted upon were of exceedingly different degrees of hardness. This caution, then, I wish to be applied to all I am about to say. Even unaided by concentration of force in the form of torrents, the atmospheric waters are powerful in eroding the mountain rocks, provided their substance be loose and porous; no better example of which can be given than the Slieve Mish mountains in Kerry. That extensive range extends from Tralee to Brandon Head, about thirty miles, and forms a narrow neck or partition between Tralee and Dingle Bays, the height of Brandon mountain being 3120 feet, and that of Bartrigoun, at the other extremity, 2796. With the Brandon end I am not at present personally acquainted; but the other end, the great mass of which is sandstone and conglomerate, has been worn into distinct tops, connected by narrow ridges, the edges of which are so thin that they afford a path for one pedestrian only at a time, whilst their sides slope steeply down towards the base of the mountain. These ridges form a descending curve between the tops; and so disintegrated and loose are the yet adhering fragments on their edges, and so tottering are many of the greater masses on their sides, that it is impossible to avoid seeing that they are rapidly lowering in elevation, and thus gradually forming the more enduring portions between them into isolated and conical mountains. To their sharpened crests and to the deep, wide, and secluded glens which border them, I would earnestly invite the geologist, who will assuredly emerge from their sweet solitudes with exalted notions of the extent of destruction now going on, although he will admit that even in ruins nature is lovely. I have spoken of the tops of this chain as more enduring, yet have they not escaped, though they have felt less decay. It is strongly marked upon them, and at Bartrigoun may be established by numerous relics of what once had been. These are, first, large lumps of conglomerate (still in situ), the remnants of a stratum nearly destroyed, and which are themselves so worn and softened that we may anticipate their speedy disappearance. Then, again, there are hummocks of sand, covered at top with moss and grass, but on the sides eaten into by the rains; and thus as they diminish in extent every day, we see vanishing away another remnant of an ancient coating. And as one layer is thus going, another is preparing to follow it; for so completely has the surface rock been disintegrated, that to the depth of two feet it has become a bed of sand and gravel, now gradually acquiring a verdant covering, though not so quickly as to have prevented the rain from wearing numerous gullies in its surface. This new covering when become more close and firm will, in its turn, be undermined and carried in large stripes away by the winter torrents, the operation having in some places already commenced. During the last summer the appearance of these hills, arising out of the wear here explained, was singularly striking, the surface looking as if forcibly striped or scored, whilst amidst the general barrenness little green patches remained as memorials of the ravages of the waters. These are no mean effects, and yet we need not wonder at their amount when we see the water oozing out at every pore of the rock, and when by the numerous cracks in the mossy covering (where such exists) we can follow the channels of streams now pursuing their bubbling course beneath our feet, and, as they go on, eating deeper and deeper into the rock, and undermining more and more the turf above it, until at length it slides in a large mass away, and is added to the confused heap of detritus below. Nor are we to estimate the amount of the destroying agents by the ordinary standard of the lower regions, as even in the last summer and autumn, when all was smiling and sunny in the plain, out of sixty-eight days forty-four were days of clouds and wetting fog on Bartrigoun, and betwen July 29th and 5th Oct. no less than twenty inches of rain were poured out upon it, being nearly the average yearly quantity in England. If having witnessed those proofs of the destructive agency of atmospheric causes we should wish to inquire whether they are sufficient to account for the scooping out of vallies, I would remark that in all these the total excavation of which might be supposed attributable to the waters now either constantly or periodically flowing in them, we ought to find a certain similarity of figure in all parts of the excavation, from its first commencement as a ravine to its ultimate extension in the full dimensions of a valley. For, if the material remain the same so will the conditions of statical equilibrium; and, consequently, as the bed of the stream descends, by erosion of the rock, or stratum, and the valley deepens, its sides must crumble down until a slope necessary for equilibrium has been attained, the widening being, therefore, a necessary consequence of the deepening.

This view of the subject I have illustrated by a diagram,* as I consider the principle a useful one in the examination of valleys: and as several ravines on the sides of the Keeper are forcible examples of it, I shall endeavour hereafter to obtain a series of sections through some of them. There, indeed, or on the sides of any of these mouldering mountains, this class of phenomena may be studied with the utmost advantage; and I trust what has now been said will at least enable the observer to discard from his mind that feeling of inadequacy which on first comparing the diminutive stream with the wide valley in the depths of which it seems almost lost, so naturally cramps his powers of conception. Our principle will not fail us as a test when we enter those vallies of a different order which may be examined with advantage in the granite countries—such, for instance, as the north of Donegal. In them we shall find the stream occupying a narrow well defined channel, to which in figure the swelling curves of the rocky valley have no resemblance. In short, the present slopes of the valley are not necessary to insure statical equilibrium, and would not alter, nor would its breadth extend, with the sinking of the river's channel. A brother officer, Lieutenant Fenwick, has furnished me with sections taken at successive points of the courses of the rivers Lannon and Swilly, which illustrate this distinction, and lead to the conclusion that much of the form and state of such valleys must be ascribed to original formation, although the erosion of the surface even in them will, by scaling it off, gradually lower its general level, and modify in some degree its figure. To the same conclusion, indeed, we should have come by the mere consideration (as before hinted) that to cut valleys of equal extent, in equal times, out of rocks of different degrees of hardness, we must require forces of unequal intensity; and, therefore, if we may fairly ascribe the total wear of a valley in loose strata or in rocks easily disintegrated (such as conglomerates) to the rain or waters flowing in it, we with equal reason must seek a different cause for the valley of rocks resisting powerfully destruction, such as granites, homblende rock, &c. There is also another class of valleys, called by Professor Buckland " Valleys of Elevation," being, as he supposes, formed by the uplifting of the strata. And, in truth, it is impossible to conceive great disturbances of the earth's surface without some such results. In the slate districts of Ireland, mountain torrents are often found coursing along the troughs formed by the basset edges of successive layers of the slate; but I am not myself acquainted with any extensive example of such valleys. Of disturbance of the outer crust of the earth, of which they are deemed a result, sufficient evidence, however, may be found; and as a small, though striking example, I shall point to a spot between Ennis and Gort, where several huge angular masses of limestone may be seen tilted up in curious confusion, and leading to a suspicion that a dyke cannot be far off, though as yet I have had no opportunity of exploring the vicinity.

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* See Plate 1, Fig. 1.

Leaving atmospheric agents, we meet another (powerful to destroy) in the ocean; and after reading all the instances of its ravages collected together by Mr. Lyell, we might almost tremble for the safety of Ireland. But, if we resist alarm, we may indulge curiosity and study with effect the sublime cliffs of Clare, or those equally picturesque of Donegal, exposed as they both are to the full sweep of the western ocean. In those of Donegal, the solid base has been hollowed into caverns; and as the sandstone and conglomerate, though disintegrating readily, has not receded to any extent, I suppose very considerable dislocations of the subjacent rocks must occasionally take place and precipitate huge masses of the incumbent strata into the abyss. I here allude to S. League, the height of which is 1960 feet, and as the slope from top to bottom is in many places almost precipitous the grandeur of its appearance may readily be conceived.

Before I dismiss this part of my subject, I would strongly urge the necessity of at once taking steps to ascertain the amount of alteration of our coasts whether by the encroachment or the retiring of the sea; and whilst we fix the standard by which future changes may be discovered and tested, let us strive to collect all the information we can as to past epochs before the experience of another age, with its possessors, pass away.

In a previous passage I have made casual allusion to dykes and disturbances of the earth's surface, and I shall now dilate a little more upon them considering that a country in which so vast a development of basaltic rocks occurs, may be expected to exhibit many other examples of igneous rocks. Small dykes in the vicinity of the basaltic area and elsewhere have been pointed out; but as yet I have not seen any published account of a well traced dyke, continuous through a large extent of country, like the great Cleaveland dyke which traverses in part Yorkshire and Durham. In 1828, Archdeacon Verschoyle thought he had discovered the line of such a dyke extending about sixty miles through Sligo;* and I have recently learned from the officer already mentioned, Lieutenant Fenwick, that he has traced a greenstone dyke in Donegal for ten miles, and has not yet finished his researches upon it. In this description of inquiry we should restrict ourselves to too narrow a limit, were we only to search for unbroken walls of trap (more commonly called dykes); we must rather look to those isolated protuberances or hillocks of trap rocks which appear in the secondary country, and endeavour by comparison to form them into lines. For instance, in Antrim a species of trachytic porphyry (a very distinctive rock) is found; and the same rock is met with in the County of Down. Again, the hill of Allen in Kildare, Croghan in the King's County, and Knockcosthie in Westmeath, are precisely in the same straight line and are all peaks of trap. Now a careful examination of the intervening ground might either afford us intermediate appearances of the same rock, or, if not, disturbances or fractures of the ordinary strata marking the direction of the force which elevated them. It would be hazardous to offer an opinion (decidedly) on either of these examples; yet it seems rational to point them out as incentives to inquiry, and the more so as the general stratification of the country may be greatly modified by similar lines of igneous rocks which have not burst into view. And to illustrate this, I will refer to the great limestone field which occupies an area of at least ninety by forty miles. Over this large tract there is an air of horizontality, but on careful examination we find a great number of hillocks of inclined strata, wrinkling as it were the surface, and should we succeed in arranging them into systems of parallel lines, we add another illustration of elevating forces to those already derived from similar districts and from mountain chains. Or, if we rather suppose the limestone strata when depositing to have been moulded on pre-existing ridges, we get a glimpse of a former condition of the earth's surface quite as strange as that we are contemplating, and perhaps see, though we have tried to thrust her back, our theory still peeping out upon us. This parallelism of strata, and I may add of mountain chains, was noticed by Playfair, and it will surely be gratifying to discern an example of it in our own country. As correct views of stratification are essential in all such investigations as those now before us, I shall not hesitate to offer one remark upon it. The undulations of the great limestone deposit cannot often embarrass us; but on approaching the primitive rocks on its northern border, the stratification becomes exceedingly confused, and the strata appear separated into distinct systems of small basins. Here, then, we require great caution, and must guard against the error of supposing a connection between portions of strata which does not exist; and, generally, against that of believing, in too strict a sense, the continuity of stratum under stratum, when the analogy of banks of sands and gravel now forming, tends rather to show that strata have been formed along coasts, or in the edges of basins; and therefore, that though they are extended in length, they are in most cases limited in the direction of their dip. Fatal, indeed, would be the practical error of supposing that by only digging deep enough we must arrive at any particular stratum; and yet the acute philosopher I have just mentioned did not escape it, when, adding together the thicknesses of a series of strata, he assumed that we might possibly be acquainted with the substance of the earth's crust to the depth of sixty miles, or, allowing for shifts, to that of at least thirty. It needs little reflection to see the great improbability of such a doctrine, and if we were to apply it to those rocks containing and almost consisting of organic bodies, we should meet with insuperable difficulties. Let us, for example, take Mr. Conybeare's supermedial order, or those strata above the coal, and including the chalk. Their united thickness appears from M. de la Beche's excellent tabular view to be 6250 feet, or considerably more than a mile, a depth far too vast for so great a development of life even in its inferior forms; and if we merely looked to the mechanical operation of such an uplifting as would be necessary, our difficulties will certainly not diminish. Hitherto I have spoken only of that class of disturbances, the evidence of which may be sought for in dislocations of the strata from uplifting; but there is another form of appearances in which they may, though with more difficulty, be discerned. I mean depressions, sinkings, or cracks.

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* Archdeacon Verschoyle has since fully established this fact, and communicated his researches, in an able paper, to the Geological Society of London.

On this point I have yet only a glimmering of light, and therefore crave indulgence for laying my notions before the Society, on the principle of inducing examination. Looking then at the surface of Ireland, can we avoid noticing the remarkable similarity of direction of almost all the lakes and chains of lakes which intersect its area. Beginning at the east, we have Lough Strangford, stretching near N. and S. twenty miles, and on the northern prolongation of its length; Lough Larne seven miles long. Next are Loughs Neagh and Beg, together thirty miles in length, continued to the sea by the Bann on the north, and almost so on the south, by the southern Bann and Newry river, (a canal having indeed now effected the junction). And here, too, the general direction varies little from north and south. Further west we find the two Loughs Erne, in combined length more than thirty miles, and traceable, as to line of direction, by a chain of small lakes for fifty miles further south, the same general line of bearing still prevailing. In Lough Allen, and part of the Shannon, including Lough Ree and some minor lakes, we meet another line preserving for fifty miles a similar bearing, where the Shannon assumes another direction, and would appear to belong to a different system. The mean direction of Lough Conn, Lough Mask, and Lough Corrib, though the general line is more varied in curvature, corresponds so nearly with the preceding, that it may be safely classed with it. Here this north and south system stops, unless indeed we recognise an obscure continuation of it in some of the gaps of the southern coast, such as Waterford, Youghal, Cork, and Clonakilty harbours; and, if so, between them rises up the great mountain district of the Galtees, Keeper, and S. Bloom mountains, the direction of which corresponds with that of the lower part of the Shannon. More than a bare enunciation of these curious facts I cannot at the present offer; yet I may add one or two elucidatory points of detail, for which I am indebted to Captain Mudge. Referring to the outline map of Lough Strangford on the table,* it will be seen that it is joined to the ocean by a narrow gut or channel, cut (as it were) through its rocky girdle. The depth of water in this channel is in one part only forty-eight feet, and is therefore shallow as compared with the lake itself; hence, although the tide rushes in with great velocity, moving at the rate of seven miles an hour, there is always a rocky barrier opposed to the egress of the lower waters of the lake and of the mud combined with them. No state of circumstances could be more favourable for the rapid and complete filling up of this lake, even the tide in its rapid course assisting by sweeping obliquely past the entrance of the principal mud transporting river, (which enters from the S. W.) and thereby hurrying its waters, and the alluvial matter suspended in them to the upper part of the lake. That then there should be a mass of mud ten feet thick, through which, from its yet unconsolidated texture an oar may be thrust, will not surprize us; but assuredly we shall deem it remarkable, that after such a process has been going on for ages, there should, in some parts, yet be from 180 to 210 feet of water; the bottom of the lake being thus, at the present moment, depressed like a hole that quantity below the surface of the ocean. And who shall say what was once the amount of that depression? In a similar manner we find a depression or hole in the bottom of Lough Neagh, the depth of water being ninety-nine feet, so that the bottom of that lake is even now more than forty feet below the surface of the ocean; and as the general depth is also here not much more than thirty, and every thing is favourable for filling up, we may likewise in this instance see back to a time when the depression was vastly greater than it now is. Of the depth of the other lakes I have no information at hand; and indeed I have mentioned these circumstances rather as guides to our conception of the true original formation of these singular hollows, than as fully confirmatory of the views I commenced with; but explain in whatever way we may that formation, the marked and extraordinary coincidence of the line of direction in so many systems of lakes, can surely not be ascribed to chance, but strongly points to a common and simultaneous cause.

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* Plat 1. Fig. 2.

Before I leave phenomena connected really or fancifully with those forces which have torn up the crust of the earth, and poured out upon it streams of melted rock, I may enumerate some others, of which ample examples are also to be found in Ireland. Such are veins of granite cutting through gneiss, mica-slate, &c.; veins of hornblende rock; felspar veins cutting through granite; quartz veins, sometimes separating layers, at others cutting through them, of the mica-slate, and of the foliated varieties of quartz rock associated with it. These may all be seen in Connemara, where granite and quartz rock in mass are in close contiguity to each other. There remains now only one subject on which, for a few moments, I wish to dwell, and that is the distribution of detritus and the alteration of our coasts consequent upon it. On this, as yet, our information is imperfect; for although the late Mr. Nimmo published an ingenious paper on the relation of banks and shoals to the coasts near which they have been formed, clay being adjacent to slate rocks, sand to granites, &c., soundings, from which a section of the bed of the sea between them and the coast might be constructed, are yet wanting, and of course we cannot trace their progress in growth from former epochs, nor indeed until we have such soundings, and an accurate knowledge of the currents, can we conjecture what may be the possible amount even of their present increase. The magnitude of the shoals off the coast show us that the deposition has been commensurate with the destruction described in my previous remarks; and hereafter we shall see in them fine illustrations of the mode of formation of ancient shoals or banks, which have long since become a part of our regular strata. And here it is well to notice, that such beds are seldom horizontal, the sandy beaches of the sea shore often taking a slope of 30°, as may be noticed in some of the specimens on the table.* Passing over that more remote change which may be dimly seen in those isolated rocks which stud the coasts of Galway and Kerry, such as the great Skelig, I shall endeavour to show that we have some record of more palpable alteration, and I shall seek it in the vicinity of those rocks, the rapid disintegration of which has been described. There in Dingle and Tralee bays we see long spindle-shaped projections of sand, some miles in length, terminating at rocks, which formerly were isolated, as others now are. One striking example of this change I am able to place distinctly before the Society. In Smith's Kerry, published 1756, at page 361, it is stated, that " to the north of Fenit is the bay of Ballyheige, infamous for shipwrecks. This bay, from Fenit to Kerry Head is above two leagues, over towards the midst of which is a high rock called Muckolough. The shore along the bottom of the bay is very shoal and flat, and full of sand banks, over which the sea breaks with great fury when agitated by westerly winds." Many of these banks and shoals have now become dry sands, forming long narrow spits along the coast, with lagoons behind them. Again Smith says, " All the maps of Ireland and sea charts place Fenit or Fenor Island in the midst of this bay, whereas it lies close to the shore on the north side, between which and the main there is a small creek for ships, which must be entered from the north; but the passage is so narrow and foul that it cannot be entered without a good pilot."

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* The inclination of the beach having been noted by Captain Mudge, and marked on the specimens.

What a change have we here! Fenit having ceased to be an island, and the creek through which ships once passed having now given way to an isthmus; whilst we may, in his observations on preceding maps, get some glimpses of even greater changes. Tracings from Arrowsmith's map, and from Smith's, are given to place these changes in the strongest light.* And were we further to compare the two we might suspect others like them; but I only mention those which are established, as well by the text as by the map. And is not this enough to induce us to collect all documents, such as old maps, estate surveys, &c., which might add to our means of comparison? In doing so, let us not too rashly condemn as erroneous those which differ from the more recent surveys, but rather first inquire whether the differences are not in part due to natural alterations. Like the astronomers, who apply more perfect modes of reduction to old observations, and endeavour to find in them statements of the former positions of the heavenly bodies, so should we strive to cull information from documents which at first sight may appear rude and unpromising, but which in reality may contain the enunciation of very curious truths. The filling up of lakes, and the narrowing of the channels of rivers, are analogous phenomena, one of which I have mentioned in describing the depositions of clay and sand in Lough Strangford, and in this way, doubtless, many of the marl pits, so remarkable for their fossil contents, were filled up, as some are even now gradually closing. Mr. Hackett, one of the civil assistants on the survey, mentions, that within his recollection, several quarry holes on the Liffey have been completely filled up with ooze and mud. Let us, however, take a still more instructive example, and refer to the Shannon. Above Killaloe, alteration in depth, (within twenty-five years) to a small degree, is perceptible, even in the expanse of Lough Derg, and below Killaloe, a very marked decrease of depth, sometimes as much as three feet, on the lateral portion of the stream, accompanied by a deepening in the centre. To this double effect I must point especial attention, as in it we have an illustration of the mode in which many ancient alluvions, now dry and solid, were formed. First, then, we can conceive the alluvial matter depositing generally over the bottom of an expansion of the river, and this will continue until the resulting shallowness is such as to bring the bottom within the action of the in-draught of the narrow portion below; then every addition of thickness, by lessening the area of the section, must occasion increased velocity and deepening of the immediate channel. Second, when this has long continued, the lateral shallows are brought almost to the surface, and should the wearing, even to a small extent, of a barrier accelerate the motion of the water in the channel, the depth is there increased, and the whole water retiring into the now sufficiently enlarged channel the barriers are left permanently dry. The plains of Myroe, on the banks of Lough Foyle, and the alluvial plain near Londonderry, are fine examples, both consisting of layers of sand and schistose clay, full of shells, such as now live in the adjoining sea and estuary; and there are unquestionably many more of equal interest. I may indeed here mention, on the information of Lieut. Bordes of the engineers, (one of our members) that an examination preparatory to the New Dock at Belfast, has produced a very fine section quite in point. In the trials for that Dock the following were the substances met and passed through. One foot of shells, nine of blue clay, and then peat. Lieut. Bordes, however, has some doubt as to the latter, not having himself seen it; though such is the received account. The depositions in Carlingford bay might also be added as another instance of filling up, the mud being now occasionally ten feet thick. To have described in detail any one of the geological phenomena I have enumerated, would have obliged me to trespass even more than I have on the time of the Society. Such detailed accounts will, however, be the fruits of our summer labours; and I hope will throw a charm over our future meetings. In the mean time, this feeble sketch may at least have shown that active curiosity will meet its reward. Let me conclude it by requesting permission to take one flight of imagination, and to say, that if the labours of former geologists have accumulated such a mass of observations, that we stand as upon an Alps of knowledge; yet are there the pinnacles of a more lofty Andes before us, on which I trust it will be the good fortune of some of us to plant the standard of our Society.

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* Plate 2.

ON GLOBULAR FORMATIONS.

BY WHITLEY STOKES, ESQ., M. D., M. R. I. A., PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF DUBLIN.

Read April 10, 1832.

A great variety of mineral substances are found in globular or tuberose forms. These forms are produced by various causes; as by attrition, decomposition, crystallization, the crystals diverging, in filtration, into a globular cavity; the attraction of cohesion combined with rotation, sublimation; in which last case the sublimed substance on its assuming the fluid state is collected by the attraction of cohesion.

It is often difficult to determine to which of these causes the formation of a particular mass is to be referred; but a careful examination of the circumstances will generally enable us to decide. The first globular masses I shall describe, are volcanic drops thrown out from Vesuvius.

Lava drops, it is said, are sometimes perfect spheres, but they generally affect a flattened, and sometimes an elongated form, and are surrounded by a projecting zone, studded with small tubercles. Some again are thrown into the shape of a saucer. These differences depend on the degree of fluidity which the mass retains when it falls on the cone of the volcano, and the state of the materials on which it falls. The saucer shape may be produced by the edge setting first. Volcanic drops may also deviate from sphericity by other causes; they may not have had, at first, equal fluidity in all parts, or the part that adhered last to the crater may have set before the rest, and thus formed a projection.

Mr. Berkley, perhaps, the celebrated author, saw the crater of Vesuvius in a very interesting state: two cavities were in action at the bottom of the crater; in one lava was boiling, and occasionally rose and flowed out of the mouth of an interior cone; and at another, red hot balls were thrown up, which fell whole or broken into the lava ejected; by the first, then, a mass was collecting of lava or obsidian balls imbedded in a lava cement.

We may well suppose, that in the interior of the volcano, even in the bottom of the crater, the red hot balls of lava may coat themselves by revolving on their centres through an atmosphere of various vapours, in which dust and small particles might be falling, and thus balls might be formed, having kernels and concentric crusts of various composition. In support of this conjecture, we may observe that Sir William Hamilton has figured balls of white limestone thrown out by Vesuvius, having kernels of lava. Some of the gems may have been formed by rotation while in a fluid state, and have fallen into melted lava, particularly leucite, pyrope, coccolite, and succinite. Leucite often involves extraneous substances. Diamond is often inclosed in spherical triangles; but one spherical diamond was shown by Mrs. Brown, of Fownes'-street, to Sir Charles Gieseckie.

Masses of sodalte are found imbedded in eudialite, and that again in basalt; now sodalite contains 23.5 per cent. of soda; eudialite only 13.82; and eudialite contains 11.1* per cent. of zirconia; basalt most probably not a particle. It is therefore not very likely that sodalite was secreted from the eudialite; and less so that the eudialite was secreted from the basalt.

Hyacinth is found in particles the size of a turnip-seed in basalt. Hyacinth contains 70 per cent. zirconia. Basalt is not known to contain any.

Lava passes by insensible gradations into obsidian. The obsidian of Marchan in Kamtschatka is described by Patrin. Balls of glass are the exclusive covering of a considerable portion of the shore. They are not spheres; but do not appear to have lost their shape by impinging, as they preserve the original polish of fusion in the impressed parts.

Obsidian seems to differ from lava and basalt by containing a greater proportion of silex; and by being more vitrified in consequence of rapid cooling. Basalt is frequently found in the form of a mass of balls, spherical or nearly so, packed in basalt less firm: from these balls scales of large segments are thrown off. This appearance is partly owing to decomposition; but decomposition often betrays the form of the original structure. It is said that nuclei of different stones are sometimes found in the centres of these balls, particularly angular pices of carbonate of lime.—See *Journal de Physique*, 1792. Something of this appearance is exhibited in a specimen from Cinghiari, one of the Euganean hills.

The pearlstone of Hungary is an assemblage of globules from the size of a nut to that of a grain of sand; they have usually a pearly lustre and scaly aspect, adhering without intervening substance; there are intermediate substances which make a series between these and obsidian. The globules of pearlstone are connected by an enamelled paste, with a ribboned appearance, contorted as if disturbed in the act of setting. Sir William Hamilton observed in the lava of 1767, small balls like pearls; and Cronstadt obtained from Ascension Island scoriæ consisting of glassy balls cohering.—*Brerzlac Voyages* v. 2, p. 12. Pearlstone and obsidian are closely connected, and have probably been produced in a similar manner. Obsidian passes into pitch-stone, resembling it in analysis, appearance, and decomposition. Pitchstone was found in globular masses at Lipari by Scrope.—*Geol. Trans.*

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* Sodalite also contains no zirconia.	Eudalite 11.1
——————— no iron.	———— 7.75
——————— 27.48 alumine.	———— 0.

Obsidian and pumice pass readily into each other; vitrified scoriæ forming a link. The cavities of pumice, scoriæ, and amygdaloids, seem to have been formed by elastic vapours; and those of the two first closely resemble the cavities of bread. Had they been produced by the decomposition of water-worn stones, their shapes would not have been so irregular, nor their communications so long and narrow.

Flint and hornstone are nearly allied; the fracture of the latter is farther removed from the conchoidal shape and glassy lustre of obsidian, than that of the flint is. There are specimens in the collection of Trinity College, arranged by Mr. Stephens, to which these names may be applicable; they are parts of masses closely approaching spheres; some have a superficial crust, and a knob is to be seen, such as might have been produced by a projection hardening before the rest of the mass. One specimen of flint has the appearance of having been stretched, and having struck some substance harder than itself.

Menilite approaches to obsidian and pitchstone. It is found in nodules and masses resembling the tuberose roots of plants, in adhesive slates. Its appearance leads us to suppose that it ows its degree of roundness rather to original formation than to attrition.

Globules of quartz, about the size of a pea, are interspersed in mulattoe-stone of the County of Antrim, (which is said to answer to the green sand of England) and of large size in the limestone of Slieve Gallion. In the mulattoe-stone these pebbles are nearly of the size of the quartz parts of some granites. Professor Daubeny gives several instances of collections of globular quartz, particularly near Coblentz on the Rhine. At Cader Idris greenstone is found in oval masses, from a foot to a yard in length, composed of concentric laminæ, covered by a coat of an inch thick of hard calcareous spar, near a mountain lake, whose steep sides resemble a volcanic crater.—(*Geol. Trans.* vol. I. 211.) Blackball-head, in the County of Cork, which may be called talcose slate, contains balls of brilliant crystallized hornblende.

Sandstone from Skreen, County Sligo, has a layer of globules of quartz attached to it; they seem a little larger than the usual size of quartzy globules in granite. Conglomerate or red sandstone is a rock consisting of rounded pieces, and of angular fragments of various minerals and compound rocks; they very much resemble the volcanic breccias which have been cemented by heat; the grains or cemented pieces vary from a very minute size to that of several inches in diameter; they were probably united somewhat soft, for though they are very various in outline, they leave but very few insterstices. Common white quartz is an usual ingredient of this rock in Ireland.

Quartz rock is generally very free from imbedded parts of older formations; but there is a specimen of this rock from Howth that contains a round mass. Dr. M'Culloch found such in the Highlands of Scotland.

I have from the North-east of Ireland fragments of a geode of rock crystal with a slight purplish tinge; the crystals did not completely fill the cavity; the mass is almost spherical, with some projections, such as might have been produced by smaller masses running into it; one side is perfectly flat.

In mica-slate, masses of quartz are found, larger than the human head; and the layers of mica-slate appear to have formed round them.

The shale of the coal fields presents rounded forms; those which I possess appear to have been much compressed.

Cepalino, from Port Stuart, which I owe to the kindness of Sir C. L. Giesecke, contains rounded masses of one combination of lime imbedded in a paste of another differently coloured; in one of the specimens particularly, the rounded masses have opened into the paste like the head of a cauliflower; this may have been produced by the different materials assuming solidity successively; a similar cause may have disturbed the outline of the quartzy particles of our granite.

In the Italian marbles of red and white we may often observe the imbedded masses appear to have compressed each other.

Very accurate spheres of calp are in the Museum of Trinity College, and on one an even coat of pyrites has been superinduced.

Gold is found in masses, such as may have been the effect of fusion, and sometimes one drop appears imperfectly united to another.

Iron pyrites and carbonate of copper form round masses by crystallization.

Clay ironstone.—I possess specimens of very true oblate spheroids: one specimen has a distinct kernel, and the other a wrinkled coat and stones resembling clay ironstone, which appears to have been inflated while soft, and to have fallen while soft on a hard substance.

Globular formations may be traced most extensively in nature; and this sketch might have been enlarged from the writings of M'Culloch, Von Buch, Molina, Daubeny, and Scrope, and from many accurate descriptions of globular masses in the Geological Transactions. But compilement is not the object of this society. Masses which owe their roundness to their original formation may be often distinguished by some of the following marks: layers parallel to the surface; kernels; a surface of somewhat different material from the mass; a surface wrinkled as if by consolidation; and lastly, by their retaining such impressions as the external force to which they were exposed might have produced. That roundness was formed by attrition, may be made probable by the smoothness of the surface, and it becomes still more so when the surface is observed to cut the original layers.

OBSERVATIONS ON THE FOSSIL DEER OF IRELAND.

(CERVUS MAGACEROS.)

BY JOHN HART, M.D. M.R.I.A. &C.

(Read April 11, 1832.)

This paper is intended to comprise an account of the distinguishing anatomical characters of the fossil deer, whose remains so frequently occur in various parts of Ireland, together with a brief statement of its geological position.

Although many of the facts contained in it have already been made public, still some good may arise from the subject being submitted to the consideration of this Society in its present form, particularly as it may be a means of inducing some of its members who are likely to be henceforward engaged in investigating the Geology of this country, to seek after such additional information as may tend to indicate the probable period of the existence, and the complete extinction of that remarkable animal.

The earliest published notice of the remains of the fossil deer of Ireland is, I believe, that contained in a paper published by the celebrated Dr. Thomas Molyneux, in the Philosphical Transactions, vol. XIX. anno 1697. Dr. Molyneux, on that occasion fell into the error of supposing that these remains had belonged to an animal identical with the moose deer or elk of North America; and hence the origin of the name Irish elk, by which it is so generally known.

The only perfect skeleton of this animal as yet in existence is in the museum of the Royal Dublin Society. It was presented by Archdeacon Maunsell, who found it with the remains of several other individuals of the same species, in a bed of shell marl, under a thin stratum of peat, at a place called Rathcannon, near Bruff, in the county of Limerick, in the year 1824.

As I was appointed to select from the heap of bones collected on that occasion, those of which the above mentioned skeleton consists, and subsequently to superintend their articulation, my attention was necessarily a good deal directed to a close examination of their anatomical characters. I was thus enabled to draw up an account of the animal, which, with two illustrative plates, has been published by the Royal Dublin Society.

The specific characters of the deer tribe are taken in a great measure from the form of their antlers, and as these parts of the fossil animal exhibit characters peculiar to themselves, and differing from those of any known living species, the extinction of the race is a tolerably well established fact. As of all existing species of deer, the moose, or elk of North America makes the nearest approach to our fossil animal, both as to the size of its skeleton and the breadth of the palms of its antlers, it is not much to be wondered at that hasty and superficial observation should have caused the two species to be confounded. Our attention to the following particulars, however, will show how essentially they differ.

It is remarked by Baron Cuvier, that the palm of the antler of the fossil deer increases in breadth as it extends outwards; while that of the North American elk is of the greatest breadth internally. The palm of the elk's antler is directed backwards, while that of the fossil animal has a more lateral direction: it is, moreover, to be observed that the branches which project from the border of the palm are longer in proportion, and more slender than those of the elk.

The skull of the fossil deer is small when compared with the gigantic size of its antlers. In this particular there is a marked difference between it and the elk, whose skull is absolutely larger than that of the fossil animal, although its antlers are so inferior in size.

The length of the skull of the elk of North America, when full grown, measures two feet in length, while the largest of many fossil skulls which I have seen was scarcely one foot ten inches long. The breadth between the roots of the antlers in a specimen in the museum of the Dublin Society, is six and a half inches; and the distance in a straight line between the extreme points of the antlers, which are of the largest size, is three feet seven inches. In the fossil deer in the same place, the breadth of the skull between the roots of the antlers is but four inches, while the distance in a right line between their extreme points, is nine feet two inches.

Cuvier thinks it probable that the females of the Irish fossil deer, like those of the rein-deer, had antlers as well as the males. This opinion derives considerable support from the circumstance of no head of the animal having yet been noticed, which did not exhibit marks of having borne those appendages. I have often observed that the antlers were less curved, more slender, and smaller in all their proportions in different specimens of the fossil species, which, from the condition of the teeth, appeared to have belonged to animals of nearly the same age. Analogy would favour the inference, that the smaller kind of antlers were those of females, from the circumstance that the antlers of the female rein-deer are much smaller than those of the male, the differences of age being taken into account.

If the differences of the characters of the antlers and skull were not sufficient to mark a specific distinction between the fossil animal and the American moose or elk; the strong grounds for believing that the females of the former had antlers, while those of the elk of North America are without them, might be of some weight as an additional argument for considering the two animals of different species.

There is proof that the fossil deer dropped its head furniture in the circumstance of specimens of detached antlers being occasionally found, having a smooth surface on their roots, similar to that which is to be seen on the cast antlers of living deer. A plate of such a specimen accompanies the published description of the animal to which I have already alluded. Seeing that there is evidence of a shedding of the antlers, there is no reason for supposing that this occurrence did not happen annually, and that the reproduction of these ponderous weapons was not effected within a few weeks.

As to the other bones of the fossil animal, they differ from those of the existing species of deer, merely in being of a size proportioned to the great weight they had to sustain. Considering the size and weight of the antlers, which in the specimen in the Dublin Society's Museum weighed fully eighty pounds avoirdupoise, the bones of the limbs are of such a form and compactness as indicate an aptitude for being employed in the execution of swift and powerful motion.

The greater number by far of the bones and antlers of the fossil deer which I have seen preserved, were found at various depths in marl, mostly lying under peat in low situations, as at the bottoms of vallies. The bones which occur in this situation are generally in a most perfect state of preservation, so much so, as not to differ in the relative proportions of their animal to their earthy parts, from fresh bones. Some of them have even retained their periosteum, as ascertained by Dr. Apjohn, who examined them chemically.

A second locality is peat, in which remains of this animal are sometimes found. When they occur in this substance, they are mostly in a softened state, the animal part alone being preserved, while the earthy parts are removed in consequence, most probably, of the acid, which is found in peat, effecting their decomposition. Archdeacon Maunsell mentioned to me that his workmen had found some antlers in peat over marl, which were so soft that their implements went through them as readily as the surrounding moist peat. It was found next to impossible to remove them from the place where they were found.

There is a third locality in which the bones of the fossil deer have been found in one particular instance—in loam sand, composing a hill close to Enniskerry, at an elevation of about forty feet above the bed of the river which runs through that village. This is a locality in which I am not aware that remains of this animal have before been found in this country. I have published an account of the particulars of this discovery in the form of an appendix to a second edition of my paper on the fossil deer. The bones which were found on this occasion were light and crumbly on the surface; they were not chemically examined, but they appear to have suffered a considerable loss of their animal part.

The hill in which these bones were found, is one of a series of heaps of diluvial gravel, containing masses of secondary limestone, dispersed though an extensive valley, which lies between primitive mountains.

I shall conclude by quoting a passage from the appendix to my published paper above referred to:—

" The presence of these bones in the gravel, would seem to warrant the inference, that the destruction of the animal to which they belonged, was owing to the same cause which conveyed those large heaps of gravel and sand to the situation they at present occupy; and that this was the work of a vast inundation or deluge by which the surface of the country was once submerged, would appear likely, from the very striking resemblance which these gravel hills bear on a great scale, to the smaller heaps of sand and gravel left in the beds of mountain rivers after floods."

OBSERVATIONS ON A TRAP DISTRICT IN THE COUNTY OF LIMERICK.

BY JAMES APJOHN, M. D. M. R. I. A.

(Read December 12, 1832.)

Of the different rocks which compose the external crust of the earth, there are none which have more engaged the attention of Geologists than those which constitute the trap formation. Nor is it difficult to account for this. They are the depositories of a vast proportion of the simple fossils which our cabinets include, and have therefore been objects of special attraction to the mineral collector. But it is to their supposed origin in volcanic action, and to the light which they are conceived to throw upon certain points of Geological controversy, that they owe the greater part of the interest which they have excited. Werner, determined upon altogether excluding from his hypothesis the agency of fire, represents the trap formations as mere aqueous depositions. The progress, however, of Geological discovery has disclosed so many facts irreconcilable with his views, as to have rendered a modification of them indispensable.

The most distinguished Geologists of the German school now contend for two varieties of trap—the ancient and the modern, or, as they are more generally denominated, the Primative and the Secondary. And while they admit the igneous origin of the latter, they maintain that the former must be considered as Neptunian products. This opinion, when submitted to the test of observation, would appear quite untenable. There is no variety of trap sufficiently distinguished by its mineral characters, or Geological relations, from those which are upon all hands admitted to have sprung from volcanic action, to justify us in adopting a second theory in reference to the manner of its production. The *ancient* traps, as they are theoretically named, have, it must be admitted, generally speaking, a more decided granitic structure, are crystalline in a higher degree, and abound more in simple fossils than those of an alleged later date. These distinctions, however, are by no means constant, and the criterion by some relied upon of the former being limited to the primitive formations, while the latter break into and overlie the secondary strata also, being founded on a circumstance which is, in all probability, purely accidental, is susceptible of no useful practical application. The main constituents of both varieties are precisely the same, namely, felspar and hornblende, the latter being sometimes in part replaced by augite or pyroxene. These minerals, however, vary considerably as to the proportions in which they are associated, and as to the degree of intimacy with which they are blended together. When the crystals of felspar and hornblende are distinct, the rock is greenstone, and of this there are several varieties. Thus, it is fine grained when the crystals are small, and coarse grained when they are large; and, in the latter case, if the felspar be red, the greenstone is said to be syenitic. When the fine grained variety contains crystals of felspar of considerable size, it is called greenstone porphyry. Basalt is composed of such an intimate mixture of the two as to exhibit an almost perfect uniformity of structure. Some kinds of it are compact, some are vesicular, and some are earthy. The compact variety, when abounding in felspar, emits, upon being struck with a hammer, a clear ringing sound, and is hence denominated phonolite or clinkstone. The vesicular variety has its cavities frequently occupied by some simple crystallized mineral, as calcareous spar, chalcedony, or some of the zeolite family, and is then known under the name of amygdaloid. The earthy basalt is called wacke, and a stone intermediate in its texture between compact basalt and phonolite has received the name of claystone. The differences of appearance and character which these different rocks exhibit seem mainly dependant upon their respective proportions of felspar. This in basalt is greater than in wacke, and in clinkstone than in basalt. The hornblende is sometimes altogether wanting, in which case the stone becomes compact felspar; and when this contains distinct imbedded crystals of the same mineral, it is converted into a felspar porphyry. Obsidian, pitchstone, pumice, with most other volcanic products, may also with propriety be mentioned here; for their proximate constituents are the same with those of the preceding rocks, however distinguished from them by their external characters, and all have undoubtedly been formed in the same way. In countries such as Italy, Sicily, the Lipari Isles, which are still the seats of subterranean fires, specimens of all the varieties just enumerated may be found. They are also to be met with in districts in which volcanoes have not burned since the commencement of the historical æra, as Auvergne in France, and even in many parts of the British Isles, particularly the north and north-east coast of Antrim. It is, however, little known, that trap rocks abound in another quarter of this island, and even present there modifications of character and appearance which they rarely assume elsewhere. It is not my intention to enter into a geological description of the district in question, this having been already accomplished by Mr. Weaver, in his paper on the structure of the north-east of Ireland, published in the 5th volume of the Geological Transactions of London. Having noticed, however, some facts upon which he has either not touched at all, or sufficiently dwelt, I am induced, in the absence of any other communication, to submit a brief notice of them to the Society.

During a recent visit of a few days to the County of Limerick, having heard that a lead mine had been discovered about a month previously in the vicinity of Ulla, a little village situate on the mail-coach road between Limerick and Tipperary, and within four miles of the latter town, I resolved upon visiting the spot, and procuring, if practicable, specimens of the ore for the cabinet of our society. Having arrived at Ulla, I was quickly directed to the place where the ore was found, which proved to be a limestone quarry, situate about 150 yards from the village, upon the old road leading to Tipperary. The limestone was pretty distinctly stratified, the beds bearing to the magnetic E. and W. and dipping at a small angle to the N. It had a very loose and earthy texture, particularly its uppermost strata, and abounded in the fossil remains of madrepores, encrinites, and monovalve shells. As the quarry lay on the side of a hill no excavations had been made, so that its lowest part was little beneath the surface of the road. The height of the breast of the quarry was twenty feet, and the spot where the ore was found was about half-way down, or ten feet under the surface of the ground. The beds here were traversed by a natural joint about four inches in width in the direction of their bearing, which was occupied by a vein of calcareous spar, occurring in large and tolerably regular rhomboids of a yellowish-white colour, and perfectly opake. This was the matrix of the ore, for when struck with a hammer it was found to enclose galena or the well-known sulphuret of lead. The only other substances observed to be present were a few specks of copper-pyrites, and a small quantity of quartz interspersed here and there through the calcareous spar. There was no trace of white lead or of blende to be seen, and the sulphate of barytes so generally associated with galena appeared also to be entirely wanting.

The hill of Pollardstown, at the base of which the quarry is situate, rises to about the height of 120 feet above the adjacent low grounds, and exhibits an elliptical form, the major axis being nearly double, the minor about 400 yards in length, and pointing in a N. W. direction. Upon ascending this, three or four boulders of a very remarkable conglomerate were observed, the base of each being a reddish-brown trap, and the imbedded substances water-worn pebbles of the same material. To the N. E. of Pollardstown hill, and separated from it by a valley 400 yards in width, there is a second eminence of a more elongated form, and somewhat less extent and elevation. This latter known by the country people under the name of the hill of Ulla, is also composed of limestone, having the same direction and dip with that already described. At one point, however, on its S. W. side, and at two or three on the N. E. a stone was found overlying the limestone of a very interesting and peculiar description. The external surface is of a reddish-brown colour, evidently due to a coating of peroxide of iron. The cross fracture, however, is of a light slate hue, and exhibits, when examined by a lens, a few minute crystalline facets. When struck with a hammer it readily resolves itself into fragments by a distinct cleavage in the direction of natural joints, the smaller masses thus obtained still betraying by their colour superficial oxidation. The fragments also invariably affect a geometrical outline, and in a specimen lying on the table the octahedral form may be distinctly recognised. This stone has the specific gravity of 2.846, and is hard enough to scratch glass, though it yields to the knife. Before the blow-pipe it is infusible, but when acted upon for some time by the inner flame it is rendered magnetic. 100 grains of it submitted to analysis in the Laboratory of the Royal College of Surgeons by Mr. Longdan, have yielded the following results :—

Silex.	46.8
Protox. Iron	16.8
Alumen	16.4
Carb. Lime	14.4
Water and Loss	5.6
	100.

This stone is found, in the quarry already mentioned, as a bed of loose prismatic fragments of from two to three feet in thickness, lying immediately beneath the soil, and resting upon the uppermost stratum of limestone. Having, in vain searched geological works for a notice of any such mineral substance, I was for some time disposed to consider it as a non-descript species. A more diligent inquiry, however, has led me to conclude it to be a variety of columnar clay-ironstone, a substance which it resembles closely in specific gravity, composition, and behaviour before the blow-pipe.

Struck with the singular structure of these hills in which a metalliferous limestone, and one, nevertheless, abounding in organic remains, lay beneath an ironstone, which was itself once covered by a trap conglomerate, I became anxious to extend my examination to the surrounding district in the hope of encountering some other interesting geological facts, which may have escaped the observation of Mr. Weaver. This examination I accordingly undertook, and from the notes which I made upon the spot, I have extracted such facts and observations as appeared to me likely to interest the society. But before entering upon the exposition of these, it will be necessary to make a few preliminary remarks upon the general geological structure of the country in question.

If a spectator conceive himself placed on the hill of Pallis, which lies to the N. W. of Ulla, at the distance of about four miles, and looking to the E. N. E. he will have before him the Bilboa mountains, distant about six miles, and running in a N. W. and S. E. direction. Upon turning now to the S. S. W. point of the horizon, the Galtee and Slievenamuch chains, separated from each other by the Glen of Aharla, are discovered at the distance of ten or eleven miles. Both these mountain ranges, the Bilboa and the Galtee, are composed of almost identical materials, namely schist, sandstone, and conglomerate, the schist usually appearing toward the base of the mountain, resting on the sandstone, and the conglomerate at the top. In every other direction, almost as far as the eye can reach, the country is a great undulating limestone flat; this uniformity, however, being broken in the vicinity of the supposed observer by a number of small swells and hills of trap. Of these the hill of Pallis is the largest, rising to the height of 550 feet. Knock Dirk, Knock Ruah, and Kilteely hills, which are but parts of the same continuous ridge, with Cromwell, which, though a distinct eminence and somewhat out of the general line, terminates the range, come next in order of magnitude. The nearest point of the line which intersects these different hills bears S. S. W. from the village of Pallis, and is distant about two miles. The hills of Caherconlish, about six miles to the N. N. W., attain to a still less elevation, while at Drumbawn, Drumlara, Brackile, Coolenapish and Cross, places situate in the valley between the hill of Pallis and the Bilboa mountains, the trap crops out without any material up-heaving of the surface. In making a very hasty examination of this district, the points that appeared to me most interesting, were the relations of the trap with the limestone of the valley, and the great variety of aspect and character presented by the former rock. Upon each of these topics I purpose making a few remarks.

There is no question in Geology respecting which a greater difference of opinion has existed than as to whether the trap formations are or are not to be found in a stratified state. The affirmative of the proposition has been very warmly maintained by the followers of Werner, who derive from it an argument against the theory which views them as igneous products. That they occasionally occur in conformable beds is now universally admitted. Of such, innumerable instances might be adduced. But I know of no place where the fact is better exemplified than on the western side of the Dublin mountains, at Hollywood—a little village on the road from Blessington to Baltinglass. Here the mountain to the east of the village is composed of greenstone, occurring in distinct and regular beds, which dip at an angle of 70° to the N.N.W., and upon crossing a narrow valley at the foot of the mountain, a ridge of mica-slate is met with, having precisely the same direction and dip. But though it be conceded that trap occurs in regular beds interposed between other rocks, and even alternating with them, it does not by any means follow that it was formed from an aqueous menstruum. The non-conformable trap could not, at all events, have been produced in this way, and when it lies conformably between other rocks, the fact, as has been frequently suggested, may be explained by the agency of subterraneous fires rending and up-heaving the strata, and forcing melted lava through the fissures thus produced. Its imbedment also in limestone, a position it assumes in Derbyshire and other places, admits of being understood by supposing that its ejection in a liquid form took place at the bottom of the ocean, and that the incumbent stratum of calcareous rock was subsequently deposited.—Assuming the soundness of these views, it is an obvious misapplication of language to speak at all of stratified trap. When a fluid flows over a surface, and is subsequently solidified, it must, of course, form a stratum which conforms to the shape of such surface. This, however, falls far short of *stratification*, as the term is applied to other rocks. The truly stratified rocks must have been formed in succession, the lowest being necessarily that first deposited; whereas, from the manner of formation of trap, however low in the series, it may have been that last produced.

Having disposed thus briefly of this controverted topic, I have now to observe upon the geological relations of the Limerick trap. Mr. Weaver, in the paper already alluded to, represents it as interstratified with the limestone of the valley. There are, according to him, seven or eight great alternating beds of this description, and several subordinate divisions, arising from the occurrence of smaller beds of limestone in the larger strata of trap. Thus the trap of Drumlara is described as resting upon the limestone of Castleguard, and lying beneath that of Mount Catherine. And on the N.E. side of Pallis hill, over the village of Nicker, the trap is said to lie in strata, above and below a seam of limestone of about ten fathoms thickness, which he considers as a subordinate imbedded mass. Now, this view is not only opposed by the general arguments already adduced against the stratification of trap; but, as far as my observation extends, is entirely unsupported by facts. The limestone of Castleguard and Mount Catherine appeared to me to be but different parts of the same sheet, which had been elevated at some remote period by the protrusion of the trap from below, and removed in the course of time in virtue of the ordinary processes of disintegration. In confirmation of this opinion I may observe, that the trap in question dips at its north and south sides to opposite points of the compass. Thus in the vicinity of the dead river the dip is to the north, and in that of Kilduff to the south, a fact very intelligible upon the supposition of its constituting a conical mass, whose flanks are still covered by the limestone which has been elevated and disrupted by it. The structure of the north end of the hill of Pallis is of a more embarrassing kind. It is, in fact, not explicable upon precisely the same hypothesis. That we have not, however, here an instance of genuine interstratification, I infer from the very limited extent of the trap in a lateral direction. It could not, in fact, be found in any other part of the hill, though looked for with great care in the line of its apparent bearing. The appearances under discussion, though sufficiently complicated, admit of being referred to the agency of subterranean heat. But it is not necessary to enter upon this point into any explanatory details; for if the district be admitted to have been once the theatre of volcanic eruptions, we have obviously a cause adequate to the explication of geological phenomena of a much more complex character than any which are actually witnessed within it.

The most curious fact connected with the history of the Limerick trap is the extraordinary variety of character and aspect which it exhibits. The area it covers is of very limited extent, and yet within it we find examples of almost every igneous rock described in geological works. The trap conglomerate which is found in boulders on the Ulla Hills has been incidentally noticed. It consists of a base of compact felspar of a deep red colour, including fragments of the same material, many of which are water-worn. This rock may be looked upon as proving the occurrence of at least two igneous eruptions, separated by a considerable interval of time, the alluvial debris of the first being cemented together by the liquid lava ejected in the second. I do not at all events know of any other hypothesis adequate to the solution of the phenomena; for, as the cementing material is neither calcareous nor siliceous, it could not have been derived from aqueous infiltration. This conglomerate must have occupied at one time a much more extended surface than that to which it is at present confined. The wasting influence, however, of atmospherical agents have effected so completely its disintegration, as to have left but about half a dozen detached masses, to attest its former existence in a continuous bed, and its geological relations to the neighbouring rocks.

In the hill of Pallis, at the junction of the trap and limestone, above the village of Nicker, a conglomerate of a very different kind is found. In a fragment of this rock which lies upon the table, the outer crust is a reddish-brown felspathic trap, and the inner part a rock of a dark blue colour and homogeneous structure, in which trap and limestone are very intimately blended. That it includes limestone, is at once apparent upon the application of an acid, which produces in it a strong effervescence. And that the materials of trap are also present, is demonstrated by its ready fusibility before the blow-pipe. This species of conglomerate has been noticed by Mr. Weaver, who states that the base is limestone, and that the latter sometimes includes organic remains. I am not enabled to verify either of these statements. I have not observed any shells in the conglomerate, and the base has always proved to be fusible, and could, therefore, not have been a pure calcareous carbonate.

The rock of Drumlara and Brackile, and probably of Coolnapish, Cross and Knockbawn is one of a remarkable kind, and may be conveniently described here. It is to the naked eye a crystalline granitic mass of a dark red colour, mottled with specks of white, and when closely examined is found to consist in the main of ironshot compact felspar, interspersed with glassy crystals of the same mineral, and containing imbedded, here and there, nodules of an ochery trap of small size, and, generally speaking, of an ellipsoidal form. This description would make it a kind of conglomerate, having for base a felspar porphyry. From the Ulla conglomerate, however, already discussed, it is distinguished by the smaller size and number of the imbedded pebbles, and by the prevalence through it of distinct and very regular crystals of milk-white felspar. If referrible to the same origin with that on the Ulla hills, and of this there can be little question, the material which composes its base must have been erupted at a greater distance from the previously existing beds of trap, a supposition which will account for the smallness of the pebbles which it contains, and the comparatively low proportion in which they are present.

In the hill of Pallis the trap assumes a great variety of forms, every specimen picked up possessing some distinctive character, though all belong to the same formation. Thus we encounter toward the summit and central part of the hill a compact red rock analogous to that which constitutes the base of the Ulla boulders. Beds of amorphous, and blocks of figurate and spheroidal basalt are also to be met with at different points towards its southern and northern ends; also a felspar-porphyry, the base of which is highly vesicular, and over the village of Nicker, at the junction of the trap and limestone, a stone, already described, which appears an intimate admixture of both rocks, and which, as has been before suggested, is probably the trap and limestone conglomerate of Weaver. All of these are readily fusible before the blow-pipe, and all, with the exception of the red stone first mentioned, are strongly charged with calcareous spar, which is not only recognisable by the effervescence which occurs upon the application of a drop of acid, but is often visible with the naked eye, or at all events with the aid of a lens. The felspar porphyry we have stated to abound in minute rounded cavities, or to be vesicular. This character, so demonstrative of an igneous origin, is also to be observed in some of the other rocks, particularly in the amorphous basalt, to be found in different parts of the hill. In a specimen taken up at the foot of a Danish moate, half a mile from the village of Pallis, the cavities were found occupied by pisiform concretions of calcareous spar. Some of the rocks, however, of this neighbourhood, though not exhibiting any distinct streaks or nodules of carbonate of lime, will, nevertheless, effervesce copiously upon contact with an acid. In every case the calcareous carbonate may be referred to the same cause, which would appear to be an aqueous infiltration, proceeding from beds of limestone, which at some remote period were incumbent upon the trap of this entire district, but have since been removed so as to expose or denude the latter rock. I should not omit to mention, though Mr. Weaver has anticipated me in the remark, that the individuals of the zeolite family of minerals which so abound on the coast of Antrim, are altogether absent from the Limerick trap.

The Knock Dirk, Knock Ruah, and Kilteely range do not at all yield the same variety. On the first named hill, a close grained greenstone is to be met with, which graduates into clinkstone, possessing sometimes an olive-green, sometimes a red, but more usually an intermediate brownish tinge. This, which is the prevailing rock of the chain, is usually vesicular, and porphyritic, the imbedded crystals being felspar and carbonate of lime; and though the latter mineral cannot be detected in the base of the rock with the naked eye, a decided effervescence invariably occurs upon the application of an acid.

There are two places in this district at which trap may be seen exhibiting a distinctly columnar structure. At Linfield there is a beautiful basaltic facade, about eighty feet in height and sixty yards in breadth, which has been accurately described by Mr. Weaver. But the hill of Kilteely presents a still better example of trap of the figurate kind. Upon approaching this hill from the S.W. side, or from the direction of Cromwell, it presents a truly grand and imposing appearance. A conical mound rises 180 feet above the valley, and is composed to the very summit of prismatic pillars, piled upon each other, and leaning towards the vertex of the hill. Some of them are two feet in diameter, and thirty-five in length, the termination of each being a plane rectangular surface, differing little from a square, save in the truncation of one of its angles.

These pentangular pillars are so arranged that the vertical joints by which they are separated from each other, are all directed to the crown of the hill like the meridians to the poles of a sphere, a conformation which is very distinctly displayed to a spectator who travels southward round the base of the hill from its western to its eastern side. On the northern face the columnar structure disappears, and the trap becomes quite amorphous. The columns just described equal in magnitude and regularity any I have seen elsewhere, not excepting those of the Causeway and Pleskin. Their grouping, too, is very remarkable and peculiar, being disposed in the circumference of a circle, and inclined in vertical planes, which correspond with its different radii. The angle of inclination of the pillars is about 80°, so that the hill on its southern side rises almost vertically from its base. Altogether, they compose an assemblage of the most striking description; one calculated not only to arrest the attention of the geologist, but to awaken mixed sensations of astonishment and delight in the uninitiated spectator who has but an eye for the wild charms of scenery, and a pleasure in surveying the majestic and the anomalous productions of nature.

ON THE EVIDENCES OF DILUVIAL ACTION IN THE NORTH OF IRELAND.

BY JAMES BRYCE, JUN. ESQ. M.A. MEM. BRIT. ASSOC. G.S.D. NAT. HIS. SOC. BELFAST, &c.

Read 30th April, 1833.

It is well known to geologists that the surface of the earth in all countries is strewed with loose fragments of rock—they are collected into extensive deposits, filling up hollows in the subjacent strata, or forming low ridges of hills, and are then called *gravel-beds*—they are also spread out in detached masses over the surface, and are then denominated *boulder-stones*: many of them are of a rounded form, and belong to rocks which exist only at a considerable distance from the place where these fragments are now found. Masses of stone from the north of the American continent are diffused over Canada and the Northern States; the rocks of the Highlands of Scotland are spread over the Lowlands; those of the north of England are scattered over the midland counties; the spoils of the Scandinavian mountains are dispersed over the plains of northern Germany, and the Steppes of Central Russia; the ruins of the Alps strew the Austrian valleys; and detritus from the Himalaya mountains has been deposited over the dreary wastes of Siberia, as far north as the shores of the Arctic Ocean.

The agent to which the production of these striking effects is universally assigned, is water in motion; but with regard to the mode in which the currents have acted, there exists a difference of opinion. Some maintain that they may have been produced by the operation of actual causes, such as rivers and meteoric agents, continued for a very long period. Others conceive that the phenomena can only be explained by a sudden and transient rush of waters over the surface of our continents, such as the currents of the Universal Deluge are supposed to have been; though, by the way, there seems but little evidence for supposing that any great agitation of the waters accompanied that catastrophe. A third opinion has been recently advanced. M. Elie de Beaumont has demonstrated in the most satisfactory manner, that the elevations of mountain chains have been effected at different and distant geological epochs; and he contends that each elevation has given rise to a partial deluge—that in every country a succession of such deluges may have taken place, each transporting in its agitated waters the abraded fragments of the rocks exposed to its action, and thus forming a deposit of its own; and that, consequently, our present gravel-beds, or as they are called, *diluvial formations*, may have been produced at remote and different periods. The first of these theories is now nearly abandoned as untenable, and is, perhaps, only held by some ultra-Huttonians. Of the two last, that of de Beaumont seems to be gradually gaining ground; there is still, however, much uncertainty about the true theory of the formation of these beds, owing to the want of copious and accurate observations upon them.

The excavation of valleys and the removal of solid strata from situations which they once occupied, forming what are called valleys of denudation, are generally referred to the agency of the same cause.

To indicate a few of the phenomena of these two classes, observed in the north of Ireland, is the object of the following memoir—the observations which it contains will be rendered much more intelligible by prefacing them with a sketch of the general structure of that part of the country.

The district to which my observations refer comprises the counties of Down, Antrim, Derry, Donegal, Tyrone, and Armagh. The southern part of the county of Down is traversed by a chain of granite mountains, extending from Newcastle into the counties of Louth and Armagh. The granite is flanked on the south by siliceous slate, passing into chlorite slate and grey-wacke; on the north it is succeeded by the latter rock, which, near its junction with the granite, is much intermixed with hornblende rocks and porphyry: this grey-wacke occupies the rest of the county, with the exception of a small basin near Comber and Newtownards, where it is overlaid by carboniferous limestone, and new red sandstone. It extends from Down into the southern part of Armagh, and traversing Monaghan, Cavan, and Leitrim, in a broad zone, it is believed to pass out to the shores of the Atlantic. On the north the grey-wacke of Down is succeeded by new red sandstone, occupying the valley of the Lagan, in which the counties of Down and Antrim unite; extending into the county of Armagh, it skirts the southern shores of Lough Neagh, as far as the eastern angle of Tyrone, where it forms part of a coal formation of considerable extent; its course northwards will be immediately traced. The trap formation covers the remaining part of the north-eastern division of our district; it extends over the entire of Antrim, and that half of Derry which lies to the east of the river Roe, terminating on all sides in steep escarpments. From beneath this vast mass of trap, chalk every where crops out in a narrow zone, while in most places greensand and lias are found under it. These again rest every where upon new red sandstone, which thus extending from the valley of the Lagan and the shores of Lough Neagh, encircles the whole basaltic area, forming in most cases the fundamental rock on which our upper secondary rocks, and the great mass of trap repose. It should be particularly observed that the rocks younger than new red sandstone occur in no part of Ireland without the limits just described. On the south-west the basaltic area terminates in two ridges, which extend to a considerable distance from the main body; one along the western shore of Lough Neagh to the confines of Tyrone; the other, some distance to the westward, terminates in the mountain of Sleivegallion. The area between these two ridges, in the vicinity of Maghera, Tubbermore, and Castledawson, is occupied by a small coal formation, the new red sandstone, and the carboniferous limestone connected with the main body to be afterwards mentioned.

The remaining part of the county of Derry, namely, that contained between Lough Foyle on the north, and the rivers Roe and Foyle on the east and west, is entirely occupied by mica-slate: between it and the new red sandstone last mentioned there are frequently interposed strata of old red sandstone and carboniferous limestone; in other cases the schist is immediately covered by the new red sandstone itself. The mica-slate extends into Tyrone, and occupies all the northern part of that county; while the middle part of it is composed of parallel zones of clay slate and old red sandstone, running nearly E. and W., and these are succeeded on the south by the carboniferous limestone, part of the great limestone formation of Ireland. Little is yet known of the distribution of the rocks which compose the county of Donegal. It may, however, be stated generally that granite occurs in several places, traversing the county from east to west, accompanied by the only gneiss that exists in the province of Ulster,[*] and by almost every variety of the principal and subordinate primary rocks. Of the transition rocks, clay slate and grey-wacke occur also, and the carboniferous limestone abounds in the S. E. part of the county.

Such being the structure of our district, it is obvious that none could be conceived more favourable for observing the phenomena of transportation. The great diversity of the diluvial products which would be derived from the grey-wacke district of Down, the basaltic area of Antrim and Derry, the primary tracts of western Derry and Tyrone, and the greater part of Donegal, presents us with the best criterion for deciding upon the centres from which the detritus has emanated, the direction in which it has travelled, and the relative ages of the deposits. The remarks that follow may therefore be properly arranged under these three heads: the effects of diluvial action as shown, 1st. Within the basaltic area. 2d. In the primary tracts of Derry and Tyrone. And 3d. In the grey-wacke district of Down.

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[*] See note to page 3[illegible].

The whole surface of the basaltic area exhibits transported rocks in great abundance; they strew the surface in detached boulders, are collected into pre-existing cavities and valleys, or accumulated into hills. The form of these hills is at once distinguishable from that of the trap hills themselves; the latter present the form which characterises the formation in all parts of the world, and from which its name is derived,—stair or terrace-like escarpments ascending to a flat tabular summit. The gravel hills, on the other hand, have an elongated form, are generally steepest towards one side, and rise in every other direction by much more gentle acclivities. This peculiar form is so striking that the peasantry have appropriated an expressive name to such ridges; while *Knock*, *Sleive*, *Ben*, have each their peculiar significations, the names *Drum* and *Drumlin* (Dorsum) have been applied to such hills as we have been describing. These gravel hills run in a N.W. and S.E. direction, or to state it more exactly, the line of their greatest length bears from some point between W. and N. to some point between E. and S., while they are narrower in a direction at right angles to this. This general direction is preserved over the whole area, the hills being parallel at remote points; yet there are many local exceptions—they often trend from E. to W., frequently from N. to S., and in a very few solitary instances, their direcrection is from N.E to S.W.; in by far the greatest number of cases, however, the direction is that above stated—from between W. and N. to between E. and S. A striking uniformity exists between this direction and that of the trap hills, or those composed of solid strata of rock. These, whose form has been already noticed, are generally elliptical, and their greatest length is from between N.W. and N. to between S.E. and S.; The major axis of their tabular elongated summits, lying most frequently in that direction.

The hills here spoken of are those isolated masses which occur over the face of the country, and the same might also be observed to hold generally in respect of the detached summits of the two great chains themselves, which have, in fact, the same general direction. The same course is observed by the two principal longitudinal valleys, or rather that succession of minor valleys, by which the Bann and Main discharge their waters, the one out of, and the other into, the great basin of

Lough Neagh. As the drainage of the greater part of the interior of the region is effected into these two rivers, it would appear at first sight that the valleys should have a direction perpendicular to their course. But in fact these valleys have the same course as the hills which they separate, while their inosculation into one another produces a series of small transverse valleys: and it is by a succession of continual deflections from a long longitudinal into a shorter transverse valley, that the rivers, by a winding zigzag course, ultimately pour their tributary waters into the two principal rivers before mentioned.

These facts clearly indicate that the direction of the diluvial currents has been from N.W. to S.E. But it has been already remarked, that the gravel hills have a more rapid descent in one particular direction than towards any other. In short, they are, generally much steeper towards some point between W. and N. than to any other point; there are, however, many local exceptions. It would seem, therefore, that the currents have flowed from the north west. But in order to have fuller evidence on this important point, let us examine the nature of the detritus itself, and see what are the materials of which it is composed.

The gravel beds consist of clay, generally in small quantity, of sand, and of fragments of rock of all sizes, from the finest gravel to masses of very large magnitude. The arrangement which these various substances affect differs exceedingly in different localities. Sometimes they are deposited in regular strata, symmetrically with respect to a horizontal axis, or anticlinal line running in the direction of their greatest length: they are often arranged like a mantle round a vertical axis, or cone, while it frequently happens that if sections be made in different parts of the same hill, the strata will dip in every possible direction, exhibiting the greatest irregularity of disposition. The strata also undulate in various ways, even in the deposits filling up pre-existing hollows, and in many cases no regularity can be perceived, the whole being one confused mass. At the base of the hills the layers, declining into the plain, become horizontal.

The relative position of the substances themselves does not in almost any case follow the order of their specific gravities, and is so variable that no general arrangement can be observed.

So various are the contents of each individual deposit that there is scarcely one of them over the entire trap district, from which a complete series of the rocks of the north of Ireland might not be obtained. Trap, as might naturally be expected, is by far the most abundant—all its varieties are met with; but greenstone, the most common of them, is the most plentiful. The fragments are in general much larger and more angular than those of any other rock, though many of them also are very much rounded.

Mica-slate, in elliptical water-worn masses of all sizes and of all the varieties that occur *in situ* in western Derry, is the next most abundant. Granite and sienite, in all their varieties identical with those found in Donegal, are met with in great plenty, but less frequently than the preceding. The fragments seldom attain any very great magnitude, but are in most cases worn by attrition into nearly perfect balls. Well-characterized gneiss which occurs in place no where in the north of Ireland but in Donegal, is also frequent in these beds.* Quartz, hornblende rock, primary greenstone, greenstone-porphyry, are also frequently found. Many varieties of these primary rocks are so unlike any thing I have seen in this country, that I was disposed to refer them to Scandinavian origin, till our fellow-member, Mr. M'Adam, who has bestowed great attention on Donegal, remarked to me that the mineral products of that interesting county are very similar to those of Sweden and Norway, and that physically considered, (an observation also, I believe, made by Mr. Conybeare,) it may be regarded as a portion of a great primary tract, comprehending those countries, the Scottish Isles, and N.W. of Ireland.

Associated with the fore-mentioned rocks, there occur also in the gravel beds masses of conglomerate and sandstone, and carboniferous limestone, which often contains many of its characteristic fossils, chalk and chalk-flints. The carboniferous limestone is derivable either from southern Derry, from Tyrone, or from the southern part of Donegal. The conglomerate and sandstone seem referable to the strata of those rocks that lie along the borders of the mica-slate district, from Newtownlimavaddy to Cookstown. From the chalk and flints no evidence can be derived, as they occur every where round the area.

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* The mica-slate of the north-east of Antrim sometimes approaches to gneiss in its structure, and contains crystals of felspar; but this gneiss—like mica-slate, is essentially different from the varieties of gneiss occurring in our gravel beds. In the western part of Tyrone, on the borders of Donegal, gneiss occurs in small quantities, subordinate to the mica-slate of Bessy Bell mountain. Western Derry and northern Tyrone are undoubted mica-slate. Granite, with much felspar of a red colour, and small crystals of black mica, is found subordinate to mica-slate, in a single spot near the point of Tor, in the N. E. of Antrim. It is a very peculiar rock, and I have never seen it in our gravel beds. These facts overthrow any argument for an easterly direction in the diluvial currents in that part of the country.

The whole surface of the country is also strewed with boulders, which are precisely similar in species to the rocks constituting the gravel beds ; and the numerical proportion of each species is in general the same as in those beds.

As we pass towards the eastern part of our district, the granitic, schistose, and other primary masses which seem to have travelled from the greatest distances, become much fewer in number, and smaller in size than in the interior and central parts, while on the western limits of the district they increase both in number and magnitude. Along the eastern declivities of the Derry mountains, from Magilligan to Maghera, they are more numerous and larger than in any other part of the district; they often attain the size of several cwts. If we conceive that this transportation of materials took place at a period subsequent to the formation of these lofty ridges, we shall have some measure of the intensity of the force which could carry blocks of this magnitude up highly inclined planes of the varying elevation of 300 to 1500 feet.

Some local facts of interest demand our attention before leaving the basaltic area. Exceptions often occur in particular districts, to the proportional quantities of the different species of rock. Thus, along the western escarpment of the most eastern of the two ridges that terminate our area to S. W., there is a much greater accumulation of limestone and sandstone fragments than in most other places, because these two rocks exist in considerable quantities a short way to the west of this ridge, as has been before mentioned. And similar remarks might be applied to many other places. In the parish of Dunbo, near the mouth of the river Bann, small pieces of siliceous slate are found, perfectly identical with that which constitutes the western shore of Lough Foyle, and of which the greater part of the eastern half of the peninsula of Innishowen is composed. The obvious conclusion seems to be that the estuary did not exist when the transportation was effected.

A most important observation has been made by Dr. M'Donnell. He has noticed that on ascending any hill of considerable elevation within the basaltic district, the diluvial detritus diminishes in quantity, and its fragments in size, the nearer we approach the summit. The fact is of great value, because it would seem to show that the country had acquired its present variety of mountain and valley, before the occurrence of the great catastrophe which transported the diluvial products so far from their native beds. The same observer has noticed primitive pebbles dispersed over all the surface of the island of Rathlin. Mr. Conybeare mentions, that along the shores of that island, detached masses of primary rocks are frequent; and he conjectures that were the sea to retire for but a short distance, it would expose to our view the primary foundations on which the island rests. The superficial masses observed by Dr. M'Donnell cannot be accounted for in this manner; it is more probable that both phenomena have been produced by the transportation of diluvial products hither before the island was separated from the main land.

We have seen that the products of the primary tracts, to the westward of the Basaltic region, are spread most extensively over the latter—has this transport been mutual?—have the districts made an interchange of diluvial products? Let us pass into the primary tract, and we shall find that no such interchange has taken place. In no instance is chalk, chalk-flint, trap, or any product of Antrim or eastern Derry ever met with; a solitary fragment of green stone, once detected among the primary masses, forms no exception, as it may have been derived from some of the dykes which are known to exist in Donegal. No evidence can be more strong than this respecting the direction of the currents; they have manifestly flowed from the west or north-west. If they had come from the south, the secondary products of Tyrone and Fermanagh should have held a conspicuous place among the primeval records, whose meaning we are deciphering. In short, the detritus consists almost entirely of primary rocks; mica slate being here the native rock, its fragments are greatly the most abundant, and in most cases are angular. Granite, quartz, and horn-blende rock (I place them in the order of their relative importance,) occur in great abundance, of all sizes, and in forms bearing the obvious marks of long attrition. The gravel hills preserve the same character in their form and direction which they exhibit in the trap region. The local exceptions which occur serve rather to confirm than invalidate the theory of transport in a particular direction. The valleys also and rocky hills attest the action of an agent which has cut off the salient, and filled up the re-entrant angles, and taken away much from the bleak and bold character of a schistose country, by moulding their whole outline into a more rounded, and less picturesque form.

In the county of Tyrone, between Ballygawly and Strabane, Mr. M'Adam has observed large and well-defined diluvial ridges, tending in a N. W. and S. E. direction, parallel to the adjoining hills and to the course of the Morne river. They are well exposed in section by the roads in many places.

Let us now pass into the district that bounds the trap formation on the south, namely the transition slate, or grey-wacké district of Down. It is superfluous to observe, that over this wide area, the most abundant rock in the detritus will be greywacké; but it obviously affords no evidence of the species we are considering. Similar proofs, however, to what have been already adduced, are easily supplied from another quarter. Rolled masses of trap in great plenty—of chalk and chalk-flints in much less quantity, and of smaller size, and very rarely mullatto or green sand, are spread over this country so far to the S. E. as Portaferry and Downpatrick. In the N. E. angle of the county, between Hollywood and Donaghadee, pieces of chalk of considerable magnitude, and containing its characteristic fossils, are frequent; and seem clearly to point to the formation of Belfast bay at a period subsequent to the transport of these masses. These interesting facts were first pointed out to me by Dr. M'Donnell. I have found no exception to them so far as my own observations have extended.

In the open country, in the valley of the Lagan, near Lisburn, the surface becomes diversified with a succession of diluvial ridges, or Drumlins, in every way similar to those already described. Their general direction, however, is somewhat different, being from about N. W. by W., to about S. E. by E. When viewed across the line of their direction, they present the deceptive appearance of a nearly continuous ridge, having a course at right angles to the above. The detritus of these hills consists of the secondary and trap rocks of Antrim and Derry, and of a great variety of primary rocks; but in no instance was any fragment of grey-wacké found—a very conclusive fact, when it is considered that the junction line of the sandstone and grey-wacké runs N. E. and S. W. at the distance of less than one mile from the Drumlins. The primary detritus has not been all detained here; much of it, especially the granite and mica slate, has been drifted far to the S. E. and is found over the interior of the grey-wacké country. Now, had the currents flowed here from the north, we should have had no intermixture of primary rocks. If from the S. or S. W. grey-wacké should have abounded: if from the W., the carboniferous limestone of Fermanagh, Tyrone, and Armagh, should frequently occur. The actual intermixture, therefore, of primary detritus with the upper secondary and trappean rocks, plainly indicates a north-west origin for these transported materials, and the currents which bore them. The more recent origin of Lough Neagh seems thus pointed out.

In advance of the termination of the Mourne mountains to the east, the surface of the country is strewed with numerous granite boulders, which have been swept outwards by a current setting from the west. Along the southern acclivities of these mountains also there is an accumulation of these boulders. There are some on the northern side, but they are in much smaller quantity than on the southern. If this chain existed before the catastrophe of which we speak, it would give a change to the direction of the currents, and thus might the spoils, which the desolating floods snatched from its bosom, be carried out over the adjacent plains far to the N. E. The forms and direction of many of the hills and valleys over the whole extent of the country afford a similar evidence to that adduced already. A few instances of another kind may be mentioned. Lieutenant Bordes, R. E. has observed an interesting fact in the vicinity of Rostrevor. On the western side of Cloughmore, a slate mountain, a huge boulder of granite occurs; it is pitched on a ridge or summit of the mountain lower than the principal summit, and at the height of 960 feet above the level of the sea. Cloughmore is separated from all the adjoining hills by deep valleys, and the parent rock from which the boulder has been derived, is situated to the E., N., and N. W. at the distance of some miles. This is a parrallel instance to that observed on the Jura, by Saussure, and among the Wicklow mountains, by Mr. Weaver.

The Provost, in the Address at our first Anniversary, noticed the dispersion of rounded blocks of greenstone along the coast adjoining the Mourne mountains. They have probably been derived from the transition trap associated there with siliceous slate and porphyry. A similar fact has been observed by the Rev. Dr. Cooke: on the shores of the eastern part of the county he notices detached masses of a very peculiar greenstone, which he has recently discovered in a place near Dundonald. He finds also on the summits of many of the grey-wacké hills, on the west side of Strangford Lough, rolled masses of the Comber limestone, which lies at a much lower level; its colour and general appearance are such as to distinguish it very remarkably from any other limestone of the North of Ireland. On the shore of the same lake, near Mount Stewart, Dr. M‘Donnell has observed an enormous mass of greenstone reposing on a sandstone bottom. He regards it as identical with the greenstone of Scrabo, which lies to the westward beyond a narrow arm of the Lough.

The facts above detailed, demonstrate that powerful diluvial currents from the north-west have swept over the whole surface of the north of Ireland at a period prior to the formation of Belfast bay, Lough Neagh, and Lough Foyle; but subsequent to the elevation of the basaltic rocks into our present lofty ridges. But the question here presents itself—are the gravel deposits of cotemporaneous origin? Were they produced by one transient convulsion? Or are we to regard them as formed, agreeably to the views of M. Elie De Beaumont, by the operation of successive deluges? Every attempt to trace a difference of age in these deposits has altogether failed. As far as I have been able to determine, they may have been perfectly cotemporaneous. Nothing is yet known of the eras of elevation of our several mountain chains. When these epochs shall have been fixed, and when our diluvial beds shall have been thoroughly investigated with the aid of the new light that will thus be cast upon them, and compared diligently with similar formations in other countries, we may hope to arrive more near the true theory of their origin. It may, however, be permitted us, even in the present state of our knowledge, to indicate the apparent connexion between the diluvial hills and valleys, and the trap dykes; both have a similar direction, and disturbing causes acting along the same course may have combined in the production of both. Mr. De La Beche has noticed the connexion between the origin of the South Devon conglomerates, and the dykes traversing them, and conceives that the disturbances attendant upon the irruption of the trap, may have contributed in a great degree to the production of those deposits. In a paper lately submitted to the Geological Society of London, by myself, the same origin is assigned to the Cushendall conglomerates; the age of the trap dykes is determined by their piercing through the whole series of mechanical formations, without passing into the superincumbent chalk and greensand. It is probable that the origin of our dykes and gravel beds, and the formation of the bays before-mentioned, at the junction of *dissimilar rocks*, the *grey-wacké* and *sandstone*, may be all referable to some disturbances connected with the elevation of the strata. The *focus* of disturbance has certainly been to the north-west. On the whole, therefore, the most probable opinion seems to be that our diluvial deposits, as well as those of Scotland and England, have had for their common cause, that great convulsion in the north which is believed to have produced the gravel beds of North America, Germany, and Russia, and to have been cotemporaneous with a great elevation among the Alps; and which may have been also accompanied by the upheaving of our whole area, from the bosom of that ocean under which its various beds were elaborated.

Many striking effects of diluvial action are exhibited in those portions of our district where the rocky materials have been removed after their consolidation, or from what are called *valleys of denudation*. As the subject has been already treated of by Dr. Richardson, in several of his papers, with considerable accuracy of detail, though great error in theory, it is unnecessary to go into any particulars. The correction of the errors into which he has fallen, and the addition of farther instances, may, perhaps, form the subject of another memoir.

NOTICE OF THE GENERAL GEOLOGY OF ERRIS, COUNTY OF MAYO.

BY P. KNIGHT, CIVIL ENGINEER; CORRESPONDING MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS OF LONDON, AND MEMBER OF THE GEOLOGICAL SOCIETY OF DUBLIN.

Read May 8th, 1833.

Erris, having such high and beautiful ranges and groups of mountains, and of such different forms, must attract at once the eye and gratify the taste of the geologist. Commencing at the southern boundary, there is the Maume-Thomaas range, whose general direction is N. E. and S. W.; the highest point is 2400 feet, and the average height of the range generally 1700 feet. Its length from the sea at Dukell to the pass of Maume-a-rattha is eight Irish miles. This range is entirely mica slate and quartz, with its usual irregularity of dip, but generally much approaching to vertical. From the summit southward (out of Erris,) diverge four broad and deep glens, the sides of which are very steep. The northern, or Erris side, is hollowed out, at intervals, into deep circular excavations, whose diameters are about half a mile: in the bottoms of these are found lakes or " tarns," from which issue streams (sometimes for a short distance subterraneously) to the northward. These are called by the natives *currie*, which means literally a pit or boiler. These curries, though very like the craters of volcanoes, exhibit no volcanic appearance, or effect of convulsion, the rock on the one side and the other being the same nearly in dip and direction, or having only that various wavy undulation which mica slate generally assumes. The direction is that of the general range of the mountain, N. E. and S. W. On the southern side of this range we find old red sandstone overlieing the mica slate, and dipping southward at an angle generally of 15°. This forms a very beautiful and durable building stone. The sandstone stratum reaches to the verge of Clew bay, where we meet limestone in the archipelago of islands which crowd its head and sides.

The Maume-Thomaas mountains form only a portion of a range of the same composition which extends westward with the interruption of Achil Sound to Achil Head, and eastward to Nephin, the Ox mountains, and the mountains south of Lough Gill in Sligo, some portions of the latter being partly composed of granite. Similar strata of mica slate and quartz are continued through Ballycroy to the parrallel of Curslieve, when the rock assumes a very different appearance. The soil towards the shore is perfectly fine-grained quartz or sand, and may be supposed to be the decomposition of the mountain rock in that parallel. At the Chapel of Cross, the rock itself appears, consisting of a fine grained quartz.

Mr. Griffith seems in doubt respecting the composition of the *Curslieve range*, commencing at the pass of Maum-a-rattha, and ending at Owenmore river. The greatest elevation of this range is 2370 feet, the average elevation 1500—the length is about seven Irish miles, and the general direction N. W. and S. E. Mr. Griffith says, "The Curslieve and Knocklettar-cuss mountains are composed of mica slate, and granular quartz rock. At the summit of Corlieve the latter rock occurs, it there contains some mica, and very minute particles (I cannot call them crystals,) of feldspar. *If all rocks composed of quartz, feldspar, and mica, be granite, this is so.* But as I have observed this rock alternating with decided mica slate, I am inclined to believe it to be merely a variety of that rock in which quartz greatly predominates." If Mr. Griffith's time had allowed him to have visited Trista hill, about six miles farther westward, beyond the Owenmore river and Tarmon hill, in nearly the same parallel, within the Mullet he would have found the most decided granite, rising out of, or alternating with, mica slate. We may then conclude, that Curslieve is granite, but so nearly on the borders of the great quartz district, that it partakes in a great degree of its prevalent material; for in fact, from this in a northern and north-western direction to Broadhaven, and the north coast, the whole country is composed of granular quartz, often mixed with granular quartzose mica slate, and only interrupted at intervals by porphyritic or "whin dykes," of which more hereafter.

North of the Owenmore, in the irregular mountain range whose highest point is Slieve-fyough, 960 feet above the sea, the junction of the primary with the secondary country occurs. About two miles east of Bangor, in the valley of the Owenmore, Mr. Griffith made the following observations which I beg leave to repeat here, as some of the readers of these pages may not have seen his very interesting observations contained in the Fourth Report of the Bog Commissioners. "The old red sandstone which immediately overlies the mica slate at the base of Croghane mountain, is composed of an aggregate of quartz pebbles, and sometimes six-sided pyramids of quartz, with large included masses of red feldspar. The rock is exceedingly compact, it varies from very coarse to very fine grained; I found an average specimen to be composed of an aggregation of quartz and feldspar in nearly equal quantities and sizes. In this latter instance the feldspar is white, and apparently a little decomposed. The colour of this rock is brownish grey—that of the large-grained is reddish brown. The old red sandstone is covered by a series of rocks of slate clay and sandstone alternating. On first viewing them, as they appeared in the bed of a precipitous stream on the north side of Owenmore, I was of opinion they belonged to the coal formation; and although, upon examination, I was not able to discover any beds of coal, I am still of opinion that the beds do belong to that formation."

SECTION OF ROCKS.

	feet.	*in.*
The old red sandstone is covered by a bed of blue slate clay	3	0
Over which sandstone in thin beds	12	0
Slate clay	4	0
Sandstone	6	0
Argillaceous limestone	3	0
Blue slate clay	3	0
Grey sandstone	10	0
Slaty sandstone	15	0
Grey quartz sandstone	20	0
Clayey limestone, containing vegetable impressions	3	0
Calcareous clay, containing vegetable impressions, much resembling the substratum to a bed of coal	0	4
Black slate clay	3	0
Earthy limestone containing shells	2	0
Black slate clay	0	6
Grey sandstone	2	0
Black slate clay	0	6
Greyish blue clay slatestone	2	0
Compact limestone	1	0
Calcareous slate clay much resembling the immediate substratum to a bed of coal	0	3
Black slate clay	3	0
Greyish white sandstone	3	0
Dark grey compact sandstone	2	0
Dark friable sandstone with mica	1	0
White micaceous sandstone	6	0
	102	7

From the point where these observations were taken, the separation of the secondary country passes northward a short space, a tongue extending into Glencullen; it then turns east to the top of Sheskin and Glencolra, (for you find none of it in the vale of Glenamoy) and passing by Rahavisteen, it is distinctly seen in the shore about two miles east of Belderrig, where a considerable agitation of both strata occurs. I have not observed, west of this line, any appearance of a secondary formation; but there are alternations of light mica slate with the granular quartz rock, which is in many parts stratified and slaty, and dipping in all directions, and at as various angles. In the ravine of Glencastle I have discovered (in seeking for arch stones for some bridges,) primitive limestone, very much crystallized, and in small layers, encrusted with mica. This discovery is of some importance, no limestone having been hitherto discovered in the neighbourhood, and the people are already beginning to use it for manure.

The most remarkable geological fact in this country, is the existence of porphyry dykes of different thicknesses, but invariably preserving a strict parallelism, the direction being 27° south of magnetic west. My attention was first drawn to the existence of these dykes by the Rev. Archdeacon Verschoyle, who, having discovered them in the neighbourhood of Killala, and traced their courses westward a considerable distance, and through the counties of Sligo and Donegal, in the same parallels, desired me to look out for them at certain points on the coast of Erris, in continuation of those he had noticed thirty miles further eastward. Glencastle produced the first remarkable instance: in cutting the road through the rock there, Mr. Bald first discovered the existence of a dyke: but it delighted me greatly to find the production of the Archdeacon's eastern one, develope itself here— further on in Plaggan; then in Leam within the Mullet; and finally on the west coast. He pointed out on the map where I should find another (for at that time he had not visited Erris)—and very nearly at that place, it showed itself distinctly, of considerable breadth, and having all the appearance of the one corresponding to it observed by him eastward. I found another farther north, and one much farther south, in the parallel of Carn within the Mullet. Where these occur the dislocation and discoloration of the mica-slate is most remarkable, evidently occasioned by an agent accompanied by a great degree of heat. The usually dark mica-slate becomes light grey, it is disturbed in all directions, and crumbles into dust when exposed to the weather. It is to be hoped that Archdeacon Verschoyle will give to the world the very interesting observations he has been for some years collecting on these and other geological facts, in the northern parts of Donegal, Sligo, and Mayo.

I have before mentioned that Tarmon hill, at the southern extremity of the Mullet, is composed of granite. It lies in beds of various thickness, from four inches to four feet, dipping south at an angle of 10°. It is very close grained; the mica is in small quantity, and the feldspar of a flesh colour, which gives this rock the appearance of the Egyptian granite. It is a fine working stone, and used in building all the piers and most of the good houses of Erris. At the west end of this hill, on the shore near Surgeview, I observed veins of quartz, of different shapes and sizes, irregularly traversing the granite, in a very curious manner. Farther north, and west of the signal tower, on the shore, there is decided mica-slate with a large proportion of hornblende; and this is the only rock found in the opposite Islands of Inniskea, and in Divillaan. In some instances it is traversed by veins of flesh-coloured feldspar. It would seem as if the granite hill of Tarmon had rested on the mica-slate, or forced its way through it; for at Kanfinaltha, on the eastern side of the bay of Blacksod, there is mica-slate of the same description as that of the west shore of the tower. The stratified appearance of the granite shows itself distinctly at Blacksod point at the eastern end of the hill; at Surgeview it has not the same appearance of stratification, but appears in irregular fragments.

North of Tarmon hill the whole of the peninsula is composed of a kind of slate rock, having large streaks of red feldspar, mica, and hornblende, and very wavy in its structure; the general direction is east and west, with a dip, like all mica-slate, very various. In many parts the grey or black mica-slate occupies a considerable tract, in others the rock is almost exclusively flesh or red brick-coloured feldspar, with little mixture of mica. When the feldspar and mica are in nearly equal beds, this stone has an uncommonly pretty variegated appearance, and is then a tolerably good building stone. A floor or paving of them, set on edge, where the variety of the colour would appear, and roughly polished, would be handsome and curious. I find Mr. Griffith has observed a variety of this slate at Knocknalyna, near the entrance of Broadhaven, and, with Jameson, calls it hornblende slate. Outside the peninsula, along the Broadhaven shore, and the north coast, I have not observed any other formation (with the exception of the whin dykes,) but granular quartz rock, having mica occasionally in beds and intermixed.

Mr. Griffith's section of the alternations in the secondary country, will suffice to show the composition of that portion; but I may add, that in the soil, limestone in boulders and gravel is found in considerable quantities, and has been judiciously applied at Sheskin, by Mr. M'Donnel, in reclaiming his mountains. The sandstone of this secondary country is whitish, and close-grained, and peculiarly well adapted for building. Mr. Bald used it for the bridge of Corick, where it looks to great advantage. The limestone burns brown, and is good as a water cement.

Soils being usually (except where great alluvial masses are found, as on the plains) the decomposition of the rocks which are found in the country, we find a great mixture and consequent fertility of soil in the secondary country. In the quartz country, very little below the surface, is dug up a beautiful white siliceous sand. Within the Mullet it is again various, from the mixture of component parts, containing also a considerable portion of the sand which stretches in hills of various elevation along the whole west coast, from Surgeview to Tarmoncarra, eleven Irish miles, and which in storms is carried over the adjacent country to a very great extent, rising in clouds upwards of fifty or sixty feet on these occasions. In this sand there is a considerable quantity of shell particles, and small specks of mica, and hornblende. The existence of these masses of sand on this western coast, and in other parts, N. Inniskea, Doohooma, Dooyork, Doolough, Doocreeghan, and Doona on the east side of Blacksod Bay, and Doonkeeghan near the entrance of Broadhaven, is not the least remarkable geological fact in Erris. Another curious fact occurs on the western coast opposite Leam. *At* and *under* the level of high water, and covered on the land side by sand banks from thirty to fifty feet in height, *bog-soil* is found, though none exists at present within two miles of it; it is so compressed, that it has nearly the appearance of coal, and produces a very lively fire. At Cartron, within the Mullet, and at Doona in Ballycroy, stumps and roots of trees, standing as they grew, are found far under the level of high water, on the shore, resting on bog-soil, which has only a slight covering of drift-sand over it.

In describing the soils of a country as the decomposition of its rock, the ingenious theory of the late Mr. Nimmo in applying this decomposition to the perfecting of our charts and soundings, in approaching the shores of any country whose geology is known, forces itself on our attention, as one extremely useful, and worthy the consideration not only of the geologist, but of the scientific hydrographer.

I have dwelt somewhat at length on this subject (geology), because in new countries, like Erris, it is of importance to know of what it is composed, for the various purposes of agriculture, in applying the proper manures, and calculating the expense for carriage, &c., as well as for building and for many other uses.

There are no mines as yet discovered in Erris: with respect to coal, Mr. Griffith has already said—"I am still of opinion these beds belong to the coal formation." And again in another part of his report—"Though I did not observe in either places (Erris or Ballinglen) any immediate traces of coal, I am still inclined to think they may be met with in the country." Bog-iron ore is found in different parts—at Clooneen, within the Mullet, near which Sir Arthur Shane formerly built a furnace for smelting; but either from want of ore, or not having charcoal to use, turf being tried as a substitute, it was given up. Crystals of quartz are found in Knocklettar-cuss, near Bangor, as well as in many other parts of Erris.

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The next subject to which our attention is directed in this paper, is the distribution of detritus on the coasts, and the changes consequent on it. That shoals and banks are thus formed, is evident from a comparison of the substance of which they consist, with that of the coasts near which they have been formed—clay being adjacent to slate rocks, and sand to granite, &c. But to estimate the rate of increase of those shoals, we should have soundings of the sea between them and the mainland, together with exact observations on the direction and force of the currents; and being in want of these, the best method we now have of forming this estimate is, by comparing the present appearances of the coasts, with the descriptions given by ancient writers—such as Smith, in his account of Kerry, from whose work the writer adduces several remarkable and interesting examples.

Finally, as the filling up of lakes, and the narrowing of beds of rivers, are phenomena of the same kind, he directs our attention t6 these latter subjects; and after adducing several examples from the Liffey, from the Shannon, in the neighbourhood of Killaloe, and from the banks of Lough Foyle, he explains the process by which such changes are effected. The alluvium is deposited near the banks where the force of the current is least, and thus the shoals are ultimately brought to the surface of the water; the rapidity of the stream in the main channel is thereby increased, and the process of deepening in that part consequently accelerated. This will be more especially the consequence of the wearing down of the barrier at its mouth; and when in any way the bed is deepened, the lateral shoals already brought to the surface, are then completely deserted and left dry. An examination of the bottom, preparatory to the construction of the new dock at Belfast, has brought to light some remarkable facts, seeming to confirm this theory.

Such are the phenomena to which this writer has directed our attention, and such the remarks which he offers for the direction of our inquiries, in this interesting paper. He concludes it with the most encouraging anticipations of the results of the labours of this Society, and which, I would beg to be permitted to say, no person is better qualified to realize, than the writer himself.

On the same night on which this paper was communicated, a letter from Mr. Molloy was also read, on the occurrence of peat beneath certain parts of the City of Dublin, together with a paper by Mr. Harte, on the fossil deer of Ireland.

At the beginning of this latter paper, the writer states that he is induced to make this communication, chiefly in the hope that it may lead some of our members to seek additional information, tending to indicate the probable period of the existence of that remarkable species, and the cause of its complete extinction in the island.

Having been appointed to select the bones of that extraordinary skeleton in the possession of the Dublin Society, and consequently to superintend their articulation, the writer was led to a close examination of the anatomical characters of the individual, and chiefly of the antlers, which exhibit the most striking peculiarities for distinguishing the several species of that tribe of animals. The moose, or elk of America, approaches nearest to it in the size of the skeleton; but the differences he has noted, in the size and form of the antlers, place it beyond all doubt that they are two distinct species.

This conclusion is strengthened by a comparison of the skulls; those of our fossil deer being much smaller, whilst the antlers they carry are much larger, and more branching.

To these characteristic features, which have been fully established, may be added the grounds for believing that the females, as well as the males of the fossil deer, were furnished with these ornaments, the females of the American elk being without them.

The period of the existence of these animals is to be guessed chiefly from the localities in which their remains have been found.

They are found in marl under peat—in peat itself—in sand-banks—that particularly which is met with as we descend into Enniskerry, from the road leading through the scalp.

The bones found in the marl were in the best preservation—differing nothing from fresh bones in the proportion of animal to earthy matter.

Those in the peat were so soft that the tools of the labourers went through them as easily as through the peat itself: the animal part alone remaining, the earthy part having been taken up by the acid of the bog.

Of that found in the gravel bank of Enniskerry, the animal part had been absorbed; the earthy parts alone remaining; and as the alluvium of this place, in all but the greatness of its mass, resembles the gravel heaps accumulated by mountain torrents, it would seem to have been the work of some vast inundation, by which the surface of the country had been once submerged: a circumstance which seems to point to the cause of the extinction of the species.

In a paper communicated by the Secretary, on the 13th June, from Captain Portlock, the writer enters more particularly into his theory of the changes which naturally occur in the beds and embankments of rivers; and of that theory the following is an abstract:

The mud or other detritus carried down the stream will continually accumulate at its bottom, until this rises to the level of the bar, or other obstruction at its embouchure. When the bottom shall have attained this level, the deposits will be confined to the margin, where the force of the current is comparatively feeble, whereby these banks shall be raised until they reach the surface of the stream; and finally, the bar being more or less subject to wear, according as this is depressed, the river cuts deeper into its channel, and the general level of the water-way thereby sinking, the banks shall be left dry. Thus the general tendency of rivers is to diminish in breadth, whilst their channel deepens.

To subject this theory to the test of observation, the writer proposes that we should examine the flat adjacent to the Liffey. We all know that the valley of the river is included within the high grounds of the Phœnix Park on the north, and those on which stands the Royal Hospital on the south. He supposes that these had constituted the ancient boundaries of the stream, and that the flat between these high grounds and the river, on either side, was formed in the manner here described.

Now, whether the soil in this part consists of alluvial deposits, may be easily ascertained, by inquiring of those who have been engaged in building the quay walls, or any edifices requiring deep foundations, or even the sinking of wells, in this site.

The marl-pits, so frequently met with in this country, and to which he alluded in his former paper, he conceives to have been the remains of former lakes, or of the enlargements of rivers, which had been filled up in the same manner.

These marl-pits derive great importance in the mind of the Geologist, from the animal remains which have been found imbedded in them, and the indications of changes of climate thereby afforded.

Thus, the fossil deer of Ireland, though proved by Mr. Harte to have belonged to a species distinct from that of any living aninal, cannot be supposed to have differed materially in its habits and temperament from the elk of North America; and if this be admitted, we are led to believe that the climate of Ireland must have been at one time much colder than it is at present. Nor is this the only mark of change of climate which meets the eye of the Geologist in these countries; for Mr. Lyell observes that the remains of elephants are never found in peat, from which he concludes "that these animals had ceased to live in those countries, before that the atmosphere had acquired that cold and humid character which favours the growth of peat." By these remains we are brought back to a period when the climate of this country was dryer and warmer than at present, as by the remains of the fossil deer we are furnished with indications of a subsequent descent to a temperature even lower than the present. Indeed the proofs are too numerous and too cogent to admit of any doubt that the temperature of these regions has undergone very striking changes. And for the causes of these alterations it seems unnecessary to go back to those distant epochs at which the condition of the earth may be supposed to have undergone any sudden or universal revolution, inasmuch as the causes now in operation seem to be sufficient to account for those variations of climate, indicated by the fossil remains of animals even so very different in their constitutions as the elephant and the elk.

The quantity of ice in the arctic seas, is, no doubt, subject to great changes of alternate accumulation and disruption, and consequent dissipation. This is easily conceived ; for the accumulation of ice in those seas, no less than in the Alpine regions of Europe, must be progressive, until by the extent of surface exposed to the currents, it encounters a force which it is no longer able to resist; it will then break up and drift; after which, the coasts shall continue for some time comparatively clear and open, to be blocked up again by the same process of accumulation.

Now, the effect of the approach of an iceberg to any of the northern shores, in depressing the temperature and even in blighting vegetation, is too well known to permit us to doubt that the influence of the northern ice must extend far into the regions of the temperate zone; though we should be unable to ascertain the period of the alterations in the extent of those influences, for want of sufficiency of observations. Such accounts as we have, relative to the state of the Greenland coasts, would seem to make it about 400 years. About the year 1400, that coast was open, and the country had then maintained a constant intercourse with Norway, from which it had been colonized. Shortly after, all communication was intercepted by the vast fields of ice which had accumulated along the whole of the shore, from the southern promontory to Spitzbergen, stretching out from the land to the distance of fifty miles.

The accounts of Captain Scoresby, and of other whalers who have lately visited those seas, have led to the belief that they were then again comparatively clear ; and it was this opinion that induced the government to make another attempt to find out the north-east and west passages.

But they are not merely the changes of our climate that we are to ascribe to these alterations in the condition of the Arctic seas. It seems not unreasonable to suspect that in the same may be found the cause of the variation of the compass, and of the variation of that variation.

But to return from this digression to the objects of this Society.—In November we were favoured withanother paper from Captain Portlock, communicated through the Secretary, on the basaltic field of the north of Ireland, in which the writer justly complains of the little attention bestowed by Geologists on that extensive formation, covering almost the whole of the county of Antrim, and spreading into the neighbouring counties. For though it has been frequently and minutely examined near the coast at its upper edge, little has been done to ascertain its exact boundary, or the diversities of the characters it presents. On these subjects, the writer expresses a hope of being able to make some communications from his own personal observation; and in the mean time he offers the following suggestions :—

As we trace the boundaries of the underlying or chalk formation, from the eastern coast by the north, and then southward as far as Moira, we have an area, including Lough Neagh. And when we notice the regularity of the coal, and other underlying formations at the opposite, and therefore corresponding points of this area, he thinks we have no mean evidence of the existence of a great calcareous basin, similar to those of other volcanic countries. This opinion seems to be confirmed by the occurrence of springs. These are to be found every where within this area, by sinking to a moderate depth; whereas, were the basalt of a very considerable thickness, they would often be sought in vain.

Another interesting fact, communicated by this writer, is that of the occurrence of beautiful basaltic columns near Shane's castle, on the northern shores of Lough Neagh. The exact similarity of these with the pillars of the Causeway, in their material, size, and structure, seems to favour the opinion that they were parts of the same stream which had descended from the north-west of this country, whilst that on the east, being of a coarser texture, would seem to belong to a different epoch: seeing that in volcanic regions devastated by successive eruptions, there is always a marked difference of character between those streams, corresponding to the difference of their sources, or of the times when they were emitted.

The opinion, that the basalt at Shane's Castle had flowed from the north, is further supported by the inclination of those pillars, which is to the south, the direction which they would naturally take, if the fluid mass of which they were formed had descended from the north, the lower part being necessarily more retarded by friction than the upper.

The writer also directs the attention of those who may visit this spot, to the huge spheroidical and scaly masses which are there found in connexion with the perfect columns, as a striking indication of the mode of formation of these last; and, indeed, when we compare this fact with the result of the experiment made by the younger Watts on the fusion of amorphous basalt, we can have little hesitation in ascribing the joints of the columnar formation to the expansion of those globular masses which appeared in the process of cooling, pressing against each other before they were perfectly consolidated.

In the concluding part of this paper, the writer adverts to the difference of character observable in those heaps of gravel which cover a large portion of the country, of which some have been evidently arranged by currents, whilst others appear to result from the decomposition of the more perishable trap-rocks. Those hugh detached lumps of basalt which are scattered over this area, suggest the inquiry, whether they are the remains of a stream of lava, or whether they have been removed from their natural beds by extraneous agency. This latter notion is, perhaps, the first that would occur; but the confidence with which it may be entertained must be shaken when it is perceived that they often repose on masses of loose materials.

On the same night, a communication was made by Mr. Molloy, relative to the conglomerates on the beach at Kingstown. And finally, on the 12th December, a paper was read by Doctor Apjohn on the trap formation of a district in the county of Limerick. The writer informs us, that during a visit made by him to a lead-mine recently opened at a place called Ulla, about four miles from the town of Tipperary, his attention was attracted by two remarkable rocks, occurring in the immediate vicinity of the ore. The one a species of columnar clay ironstone, whose mineral characters and analysis are subjoined. The other a very remarkable trap-conglomerate, occurring as a boulder, on the summit of the hill, at whose base the lead was found. The singularity of this latter rock induced him to extend his observations to the trap hills of the neighbourhood, of most of which he gives a geological sketch, dwelling principally on the varieties of character which this rock assumes in its different localities, and on its geological relations to the limestone of the valley. On this latter subject he advances some opinions at variance with those expressed by Mr. Weaver, in his paper on the north-east of Ireland, published in the 5th volume of the Transactions of the London Geological Society; wherein that author contends for a regular interstratification of the trap and limestone of the district. This view Doctor Apjohn rejects, as being opposed by the facts which had fallen under his observation, and he endeavours to show that the most complicated appearances which the two formations present at their juncture, are explicable on the supposition that the trap (of course, when in a fluid state) had been forced through the limestone strata.

The paper concludes with the description of the hill of Kilteely, which is composed of enormous pentangular pillars, of very regular figurate basalt.

A collection of specimens, illustrative of the trap rocks of the district in question, of the lead ore, and of the great limestone field, in which the trap occurs, accompanied this paper, and is now in the possession of this Society.

Such is a summary of the contributions made towards the knowledge of the Geology of Ireland by this Society during the year. It is unnecessary to speak of their value, which all will admit; but it may be proper to say a very few words relative to their number, which is not, perhaps, so considerable as some might expect. All such I would beg leave to remind, that the works we have been reviewing are the first efforts of an infant Society, and that if it has not exhibited any signs of precocity, this is no cause for despair. Let it be remembered, that the principle of vitality in such institutions consists in the interest taken by the public in their proceedings and their welfare. Let this interest be sustained, and we may feel assured that the knowledge which it is the object of this society to cultivate will be extended; that the number of its working members will necessarily increase; and that, by the fruits of their exertions, they will, ere long, make to the public an ample return for all the care which has been bestowed on its establishment, or which may be further required to advance it to a state of maturity.

ON THE GEOLOGY OF THE NEIGHBOURHOOD OF THE ALTEN MINES, IN FINMARK.

BY JOHN PETHERICK, ESQ.

Read December 11, 1833.

To the Secretary of the Geological Society of Dublin.

SIR—I beg to present to the Geological Society of Dublin a series of Specimens, collected by me, during a visit to the Alten Copper Mines in Finmark, for the purpose of reporting on their prospects. The nature of my avocations admitted but a temporary attention to the geological features of the country, and that, coupled with a premature setting in of winter, circumscribed my researches to the more immediate neighbourhood of the mines.

The Alten Mines are situate in the small Bay of Kääfiord,* near the mouth of the Alten River, on the coast of Finmark, at the base of a range of mountains, which run nearly North and South, terminating on the western coast of Finmark, near the North Cape; the distance from the base of the mountains to the main ocean being about thirty miles. They are situate about 100 miles south of the North Cape, and half that distance south of Hammerfest.

The cliffs on the north side of the bay rise by gradations, one above the other, towards the range of mountains, (which are, according to Von Buch, 3500 feet in altitude,) but on the south side the cliffs are very abrupt precipices, ranging from 1000 to 1200 feet in height, and rising nearly perpendicular above the waters of the bay.

There is a constant current setting in against this coast from the west, and American timber is frequently brought by it to the shores of Finmark. Along each side of the bay, most regularly formed terraces of water-worn stones, sloping downwards at an angle of from 30° to 40°, are particularly observable. They rise one above another in regular gradations, and are evidently formed from the debris of the surrounding cliffs and mountains. Indeed it is impossible to look at them without the conviction, that they have been at a more or less (though unknown) remote period, thrown up by the sea; which, however, is at this time from twenty to thirty feet below the bottom of the lowest range, even at the highest tides. These terraces of rolled stones contain, along with the prevailing rocks of the district, others of schist, gneiss, &c., which are not observable upon the line of sea coast. An inspection of these terraces left an indelible impression, that the sea has either retired from the coast of Finmark, and left a large space of ground which it once covered; or that the range of the sea coast of Finmark must, at some distant time, have been very considerably raised by a power acting from beneath.

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* Pronounced Kōfōrd.

The prevailing rocks of the sea coast, both north and south, as far as they were traced for a very considerable distance, is hornblende rock of a very dark colour, containing a large portion of iron disseminated throughout, in the form of an oxide.

The specimens of hornblende rocks are from Kāāfiord Bay, in which the mines occur, and through which rock the principal lode of copper is worked, by levels driven horizontally into the side of the mountain, nearly 300 feet above the sea level. This lode is principally composed of calc-spar, but is accompanied by some quartz; and contains copper-pyrites disseminated throughout its whole width, which is about fourteen feet. This and the other lodes hitherto worked occur in the compact hornblende rock. The direction of the principal lode is N.E. and S.W. It dips towards the north, at an angle varying from 10° to 40° from the horizon. The other lodes vary in their dip, some inclining towards the north, whilst others underlie in the opposite direction. In this formation there are an immense number of lodes, and they are all more or less productive, even near the surface. Occasionally isolated masses of copper ore (sulphuret of copper) are found, some containing several tons of ore; but none of a very considerable extent. They appear to be deposits in chambers of the rock, without any metallic vein connecting them with any lode, or with each other.

This formation (the hornblende rock) is sometimes traversed by slate of different kinds, alternating with each other, and lying in a highly inclined position. Thus, a course of chloritous slate about five or six fathoms in width, runs in nearly a parallel direction with the principal lodes of copper, and dips towards the north in an angle varying from 20° to 25° from the horizon. This has been traced to a very considerable extent. The summits of the mountains over the mines (before stated to be 3500 feet in altitude) are principally composed of slate rocks, which, however, contain layers of a *stratified siliceous rock*.

In the hornblende rocks, veins of *actinolite* occur occasionally, generally about six or eight inches in thickness, though sometimes of a greater width.

Lime abounds in every part of the country, and nearly all the specimens now sent, whether hornblende or otherwise, will be found to contain more or less of that substance. This fact has been ascertained by the usual tests. Almost all the lodes hitherto discovered are principally composed of calc-spar. At Talvig, about ten miles inland from the mines, in a very precipitous part of the mountain range, occurs a formation of beautiful chrystalline limestone, nearly equalling in appearance statuary marble. It is found in horizontal beds, varying from six inches to two feet in thickness. The exact aggregate thickness of these beds of limestone could not, in consequence of the precipitous character of that part of the mountain, be accurately measured; but it is probably not less than sixty feet. The beds of finer limestone are separated by layers of stratified limestone of a coarser grain, and accompanied or coloured by chlorite. The upper and lower part of this formation are composed of lime of much inferior quality, the central beds only being of that beautifully white and close grain already noticed. This limestone formation is immediately incumbent on hornblende rock, similar to that at Kāāfiord, before mentioned.

Two or three miles to the south of Talvig, in the high cliffs overhanging a bay opposite to the mouth of the Alten River, a similar lime formation occurs, which, though of a different grain, is probably a continuation of that found at Talvig; but no opportunity occurred of tracing it with accuracy. It is somewhat remarkable that that eminent geologist, M. Von Buch, in his "Travels in Finmark," does not take the slighest notice of this formation, which certainly constitutes one of the most interesting features in the geology of this district.

The "*sand-stone quartz*" of M. Von Buch, mentioned in his travels, is found at Bossekopp, near the mouth of the Alten River. It appears to be a rock of small extent, lying on a slate rock, the junction being well defined.

With regard to the *slate rocks*, such as the alum, micaceous, and other slates, it may be sufficient for me, in addition to what I have before stated, to observe that they are not found in any great abundance in the immediate neighbourhood of the mines. As before observed, the higher parts of the mountains immediately above the mines are chiefly composed of slate rocks traversed by veins of stratified siliceous rock. The alum slate is found alternating with chloritic slate, and with common slate, lying in a highly inclined position, and passing through the hornblende formation.

I am, Sir, yours, &c.
JOHN PETHERICK.

Knockmahon Mines, Co. Waterford.

ON A VEIN OF GRANITE TRAVERSING MICA-SCHIST, IN THE COUNTY OF WICKLOW.

BY ROBERT J. GRAVES, M. D. M. R. I. A.

(Read January 8th, 1834.)

Nothing is better calculated to throw light upon the origin and formation of granite than observations concerning those veins which traverse the stratified rocks called " primary."— Several extremely interesting facts connected with this subject, have been observed by British Geologists, particularly by Dr. Macculloch, who has described a very remarkable series of granite veins passing through the Gneiss at Cape Wrath in Scotland, in which place they likewise traverse strata of hornblende schist; associated with the Gneiss at Glentilt also, Dr. Maculloch observed granite veins running into the superincumbent mass of stratified limestone, and in Cornwall, veins of granite have been observed passing through hornblende schist.

Thus it appears that in England and Scotland, granite veins have been observed traversing gneiss, stratified limestone and hornblende-schist, but they have not hitherto in all probability been detected in mica-schist; if a fact so interesting had been described, there is little doubt that it would have been referred to either by Mr. Lyell or Mr. De la Beche. In America, indeed, it appears that Mr. Hitchcock has described granite veins traversing Mica-Slate. At the present moment the subject of granitic veins has assumed more than an ordinary degree of interest, having become a subject of discussion at the meetings of the British Association for the advancement of science;* and having discovered many years ago a very massive granite vein, (of which I made a sketch on the spot, and took a note of the occurrence, both of which lay by me neglected and unthought of until a perusal of Mr. Lyell's work recalled them to my mind,) I determined to submit a short account of the matter to the consideration of the Geological Society.

The coast for many leagues south of Wicklow, consists of mica-schist, evidently stratified, but much dislocated and contorted. It is smooth and shining, and forms a bold line of coast, with precipices abounding in caverns partly produced by erosion in consequence of the long continued action of the waves, but chiefly owing to contiguous rocks being disturbed and elevated so as to lean against each other, in such a manner as to leave an open space between. The great cavern under the Light House built on Wicklow Head, is evidently thus formed, and is much visited by strangers.

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* Report of the first and second meetings, p. 578.

Proceeding along the coast southward, another headland named Corrigwhee, is met with at the distance of about half a mile, and at scarcely the same distance from the latter we come to a flat reef of rocks, projecting thirty or forty yards from the mainland, and called the Long Rock. This rock forms the northern boundary of a little bay, much celebrated for its solitude, (being inaccessible from the land) and the beauty of its sandy beach, from which it is called the fine strand.

The vein of granite I am about to describe, forms for the most part the bottom of a chasm, situated at the neck of the Long Rock, and separating it from the shore*. Like most granite veins, it is extremely fine and compact, contains little if any mica, and is very white, consisting of felspar and quartz, the former in much the greater proportion. Where it forms the bed of the chasm it is about fifteen feet in breadth, and thirty or forty in length, springing up from, and again disappearing under, the sea. On either side it lies directly in contact with the mica-schist, and where it emerges from the chasm its general surface is about six feet below that of the mica-schist on either side, but on the north it rises abruptly eight or ten feet, as represented in the annexed sketch,† forming in one place a pillar, upon which rests one extremity of an arch of mica-schist. The appearance of this natural arch is very striking, and is faithfully represented in the sketch. It is evidently the result of the removal of a large block of granite from under the mica-schist, which then being unsupported, crumbled and mouldered into an arch formed in consequence of the action of the sea and weather.

The granite now descends again beneath the sea, but emerges at the other side of a little creek about thirty feet across, where it is seen forming a thick vein running up the opposite precipice. In the sketch, this precipice appears too elevated and abrupt, but the granite vein is accurately represented, except towards the top, where, as I ascertained on a late examination of the spot, it stops, or more probably is concealed from view by an accumulation of clay and debris. I had no opportunity of following it on the land, for the purpose of ascertaining the important point whether it can be traced far from the shore. In general the surfaces of contact between the granite and schist, were quite flat and smooth, but in some places the two rocks were indented, and as it were dovetailed into each other, and in more than one place insulated portions of mica schist were included within the granite—a most interesting fact, analogous to that observed by Dr. Macculloch at Glentilt, where "in some places fragments of granite appear entangled as it were in the limestone, and are not visibly connected with any larger mass, while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite*." I had not time to compare accurately the schist, in the neighbourhood of the granite vein, with that of other parts; from the comparison I did make, it appeared to abound more in quartz laminæ and andalusite. I could not find any garnets. I do not wish to be understood, however, as saying positively that andalusite is more abundant, or that garnets do not occur. These points, of great importance in determining the origin of the granite, will require further investigation. It will also be a matter of great interest to ascertain accurately, at what distance from the vein the nearest granite occurs.

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* This granite vein is seen to most advantage at the time of low water.

† See Plate.

Altogether, the appearance of this granite vein and its relations to the mica-schist, impressed me strongly with the opinion that it could have been formed in no other manner than that of fusion, and that the fused mass of granite has risen up through, and filled a rent or chasm in the mica-schist, caused by the explosive forces preceding its eruption.

NOTES ON THE BASALTIC DISTRICT OF THE NORTH OF IRELAND.

BY CAPTAIN PORTLOCK, R. E. F. G. S. L. M. R. I. A.

(Read November 22, 1832.)

In submitting to the Society a very brief notice of some curious facts, connected with the basaltic district, to which my attention was directed by my brother officers engaged in the survey of that part of the country, I shall preface it by a few remarks on the district generally. So much indeed has already been written by able Geologists on the more striking portions of the basaltic district, that it may at first appear useless to return to its consideration. Yet, when we remember that the ancient Lavas of Auvergne and of the Vivarais which engaged attention at an early period of Geological History, still furnish a theme for meditation and discussion, having called forth in our own day the complete and able work of Scrope, we may well believe that so extensive an area of basalt, will yet, in spots, perhaps, untrodden by the foot of science, disclose many facts full of instruction; and far from discouraging enquiry, we ought by all possible means to promote it, until to our mental perception the picture of the former state of the surface, and of its varying appearances whilst under the influence of igneous agencies, shall have been perfected. With this view, I shall not so much dwell on the details of isolated portions of the basaltic field, which have, in previous enquiries received full attention, but rather point attention to what is yet a desideratum, a distinct definition of its general boundary, and an explanation of the varying character of its parts, which would, together, enable us to judge whether it be the result of one great and simultaneous eruption, or is an aggregate of many successive streams. Not, indeed, that at this moment I shall enter largely on so important a subject, hoping as I do to resume it hereafter: my object is now the simple enunciation of a few remarkable facts, and their illustration by such observations only as shall be absolutely necessary.

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* Lyell, vol. 3, p. 336.

When we look at the long escarpement of white limestone (or chalk) which skirts the eastern coast of Antrim, (underlying the basalt), when we see it, after passing the primitive and older secondary rocks, again appearing in the north, and pursuing its course by Ben Guenagh, Benbrasach mountains, Galion, and several minor hills towards Lough Neagh, up to which it has been nearly traced, and when again we see the eastern line prolonged southward in an unbroken line, (for the openings or quarries upon it are now sufficiently numerous to warrant our assuming it to be unbroken,) to Soldierstown, Moira, and Magheralin leaving only the intervening space of the lake unconnected, we are naturally inclined to ask whether the basalt has not been poured into and filled a great chalk basin. And we are strengthened in this supposition when we further notice how regularly, though in small quantities, the more ancient members of the rock series appear—for if at the north-east we meet the coal, so do we find it at the south-west—if at the south-east, the new red sandstone, so at the north-west also, and here and there the Lias, with its characteristic fossils, and with oolitic beds, as has been shewn by Lieutenant Stotherd—the green sand too appearing throughout, though in very different proportions, and occupying its fitting position, immediately below the chalk. All this regularity, the great extent of the chalk line, the band of transition and primitive rocks which, except at the broken east, seems to bound the whole, and further, the deep depression of Lough Neagh, in the centre, seem, to show that there existedone great calcareous basin similar to those of other volcanic countries.

The bearing upon this question of the fact which Lieutenant Aldrich has noticed, will readily be perceived, since far within the general outline I have sketched, a large mass of chalk has recently been discovered, and is now quarrying for domestic purposes, in the parish of Templepatrick, four miles Irish from this town, and another not far from it in the Grange of Nilteen. The first I have visited, and although it exhibits strong marks of disturbance, and is mixed at parts with ochre and trap clay, it is far too large to have been moved, and must therefore, I think, be considered a portion of the great chalk basin which either was never covered by the basaltic streams, or has since been exposed by the decomposition of some less hardened portion of their substance, or has been forced up by some local disturbance. I am inclined myself to the first of these suppositions, and I must notice as one of the characteristic peculiarities, that the surface of the chalk under the gravel or detritus which covers it, is exceedingly corroded, and worn into furrows and hollows in such a manner as to indicate very violent external action either by torrents or some equivalent cause. The spot is indeed of great interest, and I anxiously anticipate from the further enquiries of Lieutenants Stotherd and Aldrich new discoveries in other localities. Nay, looking at the remarkable level character of the country in the immediate neighbourhood of the chalk, occurring as it were between two ridges (or currents) of basalt, I cannot help thinking that under the superficial crust (were it possible to excavate) would be found a continuous bed of chalk—and this notion too appears to me supported by the position of springs, which are met with at a very moderate and uniform depth.

The next fact was pointed out to me by Lieutenant Tucker, and is far from being generally known—namely, the occurrence of very beautiful basaltic columns near Shane's Castle, on the north shore of Lough Neagh. In considering it we must bear in mind that in other countries of volcanic origin in which the ancient craters yet remain sufficiently perfect to attest the points from which the various streams of ignited matter had commenced their flow, and where the course of those streams may yet be traced to demonstration—a marked variety is found to attend successive eruptions. It is not, indeed, easy to follow up to the crater's mouth the basalt of Ireland, yet, by attending to, and comparing the peculiarities of structure of specimens from its various portions, we may hope to attain some kind of insight into its source, or the direction whence it came. The fact now before us is of value in this enquiry, for with the columnar and jointed character of the basalt of the Giant's Causeway, we have the same dense structure, the same close grain, and indeed mineral identity; whilst the basalt more to the east is distinguished by a much larger and more perceptible crystallization. Whether further enquiry will discover other localities of this particular variety of basalt on the line to the Causeway, so as to establish the continuity of a current from that quarter, can scarcely be conjectured; but one curious observation of Lieutenant Tucker deserves notice, which is, that the columns of the lake all lean over to the south, which would be the case, supposing them formed from a stream moving southward,—the lower part being necessarily more retarded by friction than the upper. The speculation is one evidently of great Geological importance, as the union here of perfect columns with huge spheroidal concretions, and the pasty aspect of the latter, convince the most casual observer of the mode of their formation. The flakes of some of the concretions come off so much like slates, that they recall Mr. Scrope's description of a similar variety actually used for slating houses. Whilst the sulphuretted hydrogen which impregnates the water of a spring now led up through an iron pipe, is another link connecting this spot with other volcanic districts.

My final observations refer briefly to the apparent distinction between the great masses of gravel which cover a large portion of the country—some being evidently arranged and modified by currents, whilst others appear the result of the decomposition in situ of large beds of the more perishable trap rocks. In the latter, there is a similarity of form, size and arrangement, and an absence of heterogeneous substances. But I trust Lieutenant Stotherd, who pointed my attention to the fact, will soon have sufficient leisure to investigate it still further—and also to ascertain whether the huge detached lumps of basalt which are now found scattered about,. though apparently with a tendency to a particular direction, are the remains of a stream, or have been shifted by extraneous agency from their native bed, the difficulty of which, when we recollect they now rest *on* a heap of loose matter is considerable : and with that hope, I shall now conclude this hasty communication.

ON THE DIFFICULTIES ATTENDING THE IDENTIFICATION OF STRATA.

BY CAPTAIN PORTLOCK, R. E. F. G. S. L. M. R. I. A.

(Read March 13, 1833.)

In the cultivation of every science, except indeed of such as are of a purely abstract nature, a difficulty (sometimes almost insurmountable) has been experienced in selecting that element, character, or quality, on which might be inferred the identity of those bodies exhibiting it. In botany this difficulty has been experienced; in mineralogy also, as under the doctrine of isomorphism even crystallization has lost somewhat of its certainty; and in chemistry, too, it is not entirely avoided, since the ingenious and highly interesting researches of one of our own members (Mr. Kane) have shown, that a variation of the mode of aggregation may sensibly affect the qualities of bodies identical in composition—as, for instance, their solubility.

If, then, in the contemplation of what we may consider comparatively simple objects, our judgment is often obliged to pause, can we doubt that in considering the complicated crust of the earth—composed as it is of the relics of animate and inanimate creation, the monuments of alternate renovation and decay—we shall still more frequently be forced to hesitate, and, as it were, to spell our way through the records of nature? Such, indeed, is the case; and more particularly so when (as in geology) we seek to know, not merely the component parts of a specimen, the fragment of a rock, but the comparative epoch of that rock's formation, and the order of its association with other rocks. In this way, crystalline structure was long considered a peculiar characteristic of primitive rocks. Now crystalline rocks are recognised in every part of the series. Colour, too, for a time was supposed to mark out certain varieties of rocks, particularly limestones: white (when accompanied by crystalline structure) being appropriated to the primitive; black to the transition limestones; and white again (with a soft, earthy structure) to the chalk. But this character, though of some use, has lost its presumed value, since black limestones have been found even in the chalk formation. Again, inclination of strata was implicitly trusted: the highly inclined being considered old, or transition—the nearly horizontal, new or secondary. Now, on the contrary, more correct and extended views of the successive elevation of mountain-masses, and of the varying epochs of disturbance of the sedimentary rocks consequent on them, have stripped this character of its certainty; and we can see (without surprise) in Ireland, the transition or mountain limestone reposing in horizontal beds; whilst in the Isle of Wight, those of the tertiary are tilted up on their very edges. Such methods, then, of identifying, even approximately, strata, have failed, and would still fail; although, as auxiliaries to other methods of inquiry—such as superposition, alternation, and fossil remains—they are valuable, nay, indispensable. For instance, in a case of superposition, the comparative inclinations of the supporting and supported strata enable us to judge whether they follow each other in regular and tranquil succession, as parts of one formation, or have been separated by some disturbing operation. In alternations, structure and colour are of importance; and before we can with safety use that most powerful index to the periods of formation which is derived from the appearance and disappearance of certain organic bodies, we must combine all other methods of research; for it is evident that we require, in the first instance, to trace up the various beds or strata, so as to form a complete organic scale, and then, indeed, we may use that scale to identify isolated strata, and to allocate them correctly in the great geognostic series. It is not my intention to inquire here how far that scale has been perfected, or to dwell on the startling changes which have resulted from its use—enough, that we can trust it safely to a great extent, and that it has already cleared up many difficulties, and will be found, in most cases, efficient to remove our misconceptions or dissipate our doubts.

To illustrate the preceding remarks, I cannot do better than refer to the chalk formation; the more particularly, as it is in the great northern basin of this island at once so extensively developed and so changed in some of its external characters from its ordinary mineral type. A glance at specimens of common chalk and of our white limestone will be enough to bring before the mind the great existing difference: and its cause has in this instance been sought in the contact of basalt, as it has in others in that of granite or other igneous rocks. But as my object is to facilitate the study of this peculiar and splendid chalk basin, I shall take my example from a foreign locality, availing myself of the able paper of M. Dufrénoy on the Southern Slope of the Pyrenees, in the Annales des Mines of 1832, and prefacing my extracts by a passage from the Géologie of D'Omalius d'Halloy. "By chalk formation we mean an assemblage of rocks which, in England and the northwest of France, includes chalk, chalk-tuff, greensand, sand

and sandstones, marl and clay, all connected with the chalk, and usually pulverulent or soft. But although these mineral circumstances were long considered essentially characteristic of this formation, they are often wanting in other countries; as, for example, in the Alps, where are observed compact limestone, schists, and tenacious sandstones, unaccompanied by chalk, and yet occupying the same geognostic position as that rock. We can only, then, in the present state of the science, assign to this group, as general characteristics, its position between the tertiary and oolitic strata, and the nature of its fossils."

Here, indeed, we have had the occasional variations in the mineral characters of this formation set forth in the strongest light; and in the Pyrenees we shall find its peculiarities equally curious and striking. M. Dufrénoy describes the chalk formation as occurring on both the northern and southern slopes of that great chain, and on the southern as a continuous and extensive band. Its general characters are those essential to the chalk basin of the south of France; but there are some remarkable circumstances connected with it not hitherto noticed—such as the occurrence of numerous and thick beds of pudding-stone, the pebbles and paste of which are of the same substance, and also numerous deposits of gypsum and salt. All these are peculiarities deserving especial notice; but at present I shall confine myself to the consideration of the pudding-stone, as it appears to me in some respects analogous to what is met with in part of the chalk district of Ireland. M. Dufrénoy thus continues—"At the east extremity of the chain the calcareous pudding-stone is the prevailing rock. It extends, almost without interruption, from Castel-Follet to Berga, simply alternating with beds of marl, of marly sandstone, and of compact limestone, in which are found nummulites, milliolites, and spatangi, in great abundance." The curious occurrence of gypsum is then mentioned, and those singular appearances which seem to show that it had been forcibly intruded into the chalk. "These gypseous masses are often accompanied by saline springs, and sometimes associated with rock-salt. The salt of Cardonne, so remarkable for its purity and extent, is included in beds of sandstone, subordinate to the formation we are now considering. This sandstone is not quite similar in character to that which at Berga alternates with the pudding-stone. It is red, with grains of quartz, and a clayey paste; in structure schistose; and, from containing scales of mica, so strongly resembles the grès bigarré (new red sandstone), that any one who had not examined the country, on approaching, would take it for that rock. But when the course of the beds is followed, they are found to be but prolongations of those of Berga; exhibiting, indeed, local differences, but only such as may here, as in similar cases in Catalonia and Navarre, be attributed to the presence of the gypsum and salt." And besides that the continuity of the sandstone beds proves incontestibly the identity of this singular portion with the rest of the chalk basin, the author still more strongly confirms it by the evidence of the fossils of the limestones on which they rest. He adds, too, that "if we examine with a lens the sandstone, we find in it but little analogy with the new red sandstone. On the contrary, we find it identical with the sandstone of Berga, containing, like it, fragments of limestone, and effervescing, in consequence, with acids."

Were it not, indeed, for the evidence of position and of fossils, we might reasonably doubt that we were studying an account of a chalk formation. Such, however, it is; and the caution which such a description must have excited in our minds, will be well applied when we are examining the edges of the chalk basin of Ireland, for there, too, we shall find rocks of great ambiguity, particularly where ochreous deposits, whether original or proceeding from the decomposition of trap rocks, are in contact with, or in close proximity to, the red sandstone. The chalk of the Pyrenees has, like that of Ireland, been exposed to the action of igneous rocks, fragments of ophite (a porphyritic rock) being even found imbedded in the remarkable calcareous pudding-stones, or breccias, which have engaged our attention. M. Dufrénoy thus explains his views of the appearance of this rock in the pudding-stones, as well as of its probable influence in their formation. "It appears, then, that we must admit the ophite to have been injected into the chalk strata whilst still in a tolerably liquid state, and afterwards concentrated into nodules, just as agates are. The disturbance attending this eruption of ophite causing the chalk beds to slide over each other, and at the surfaces of contact to be grated by the friction into fragments, such as those forming the breccias or pudding-stones." Examples of this insulation of masses of basalt in chalk are to be found in Ireland; and it is singular that the same idea as to friction occurred to me, (only that I considered it friction from the semi-fluid basalt flowing over the pre-existing strata,) when examining several thin layers of angular chalk pebbles which occur in the county of Derry, above the chalk, and completely enveloped in what now looks like an ochreous alluvium—though, probably, it is a basaltic rock totally decomposed in situ. Sometimes these shattered fragments are in globular masses, an arrangement which can scarcely be explained, except by the agency of a pasty enveloping mass, such as a stream of basalt would be. I merely at present glance at these analogies between formations occupying the same geognostic position, though so wide apart on the earth's surface; and in the course of my extracts I have fully illustrated my preliminary remarks on the difficulty of identifying strata, by pointing out ambiguities which have alone been removed by the careful investigation and comparison of organic remains.

I shall conclude by the enunciation, in M. Dufrénoy's words, of a still more extraordinary mistake, namely, "the chalk taken for greywackè." "The lower beds of this formation," says our author, "are composed of a very hard sandstone, which it is impossible, by mineralogical characters, to distinguish from the greywackès, with which it has always been confounded." What stronger lesson of caution could be given than this one passage? or what stronger proof of the importance to practical geologists of such investigations?

At some future time I may resume these considerations as respects other rocks. I have selected in this instance the chalk, on account of its importance as a geological feature of this country, and of the hesitation which those who have not accustomed themselves to such inquiries feel, in admitting that rocks so different in some of their external characters are identical.

ACCOUNT OF FOSSIL EQUISETA, FOUND NEAR CARRICKFERGUS.

(Read January 8, 1834.)

TO THE SECRETARY OF THE GEOLOGICAL SOCIETY.

Dear Sir—I herewith send you specimens of some curious petrifactions which were sent me from Belfast by Mr. Francis Whitla about a month ago, which may be presented to the Geological Society. I also send you the statement I got along with them from Mr. Whitla who collected them, which you may, perhaps, think worth reading to the society. I may add that the petrifactions are evidently formed of the stems of equisetum fluviatile and limosum, or perhaps of both; the former of which generally grows in ditches and the sides of lakes and rivers, and is also very common in the county of Antrim, on dry ditch banks. The equiseta are monocotyledonous plants allied to the filices or ferns, and now form a distinct order (equisetaceæ.) They are generally marsh plants, with a verticillate arrangement of their branches, and a highly indurated epidermis. Their bark abounding in silex, they are admirably suited to the polishing of hard woods, ivory, &c. By far the most preferable kind for this purpose is equisetum hyemale, which is imported largely from Holland, but it is not of unfrequent occurrence in our woods, and may be seen in Powerscourt demesne, at Woodlands, and other similar situations. In Northumberland, Lightfoot tells they employ it in scouring and cleaning their milk-pails.

I am, dear Sir, your obedient, humble servant,

J. T. MACKAY.

5, Cottage Terrace, Dec. 11, 1833.

MR. WHITLA'S STATEMENT.

A portion of the sea shore between Carrickfergus and Kilroot-point exhibits a singular appearance. At the place alluded to, a little above high water mark of ordinary tides, the beach is thickly studded with what at first sight appear to be iron spikes (for they resemble rusted iron), standing in an upright position from two to six inches high, and varying from one to less than half an inch in circumference. In attempting to pull them up, they break off a little below the surface, and on examination prove to be hollow, as if bored quite through. It is difficult to ascertain how far they descend into the ground, but on the face of the bank adjoining they may be traced two feet and more in length; and being friable and brittle when damp, it is difficult to remove them entire more than a foot in length. After high tide the appearance is more remarkable, as they have obtained so much consistency as to be able in some degree to resist the action of the water, whilst the surrounding substance is washed away, and the tubes are then exposed standing upright. The presence of iron is strongly indicated in the appearance of the adjoining bank. In places where they have been broken off level with the surface, and nothing but the hole in the tube is seen, the observer would conclude it to be the work of some worm or insect. But in all those that were examined, there was no appearance of any thing of the kind having recently inhabited them; and the general appearance altogether inclines one to think that the cavities in the tubes were formed by a plant which had become incrusted with sand impregnated with iron. Though the plant itself has disappeared, or become so identified with as not to be clearly distinguishable from the substance with which it is incrusted, yet the form has been preserved, and the different sizes of the holes might be supposed to correspond with the dimension of the pipes of some fistulous plants. The place where the tubes are found has evidently been occupied by an equisetum—The plants in the immediate vicinity now growing are eq. fluviatile—limosum, palustre—triticum junceum, and polygonum amphibium.

The tubes above ground are all erect, and those in the face of the bank descend perpendicularly—none are seen in a horizontal position.

DR. JACOB'S REPORT TO COUNCIL ON THE PRECEDING COMMUNICATION.

I have examined the tubular productions transmitted to Mr. Mackay by Mr. Whitla, and presented by the former gentleman to the society. There does not appear to be any reason to doubt the correctness of Mr. Mackay's opinion that they are incrustations on the stems of an equisetum. The tubes are formed of coarse sand consolidated by oxide of iron. I cut several of them open on a fine grindstone, and found the interior lined by a dark brown friable material easily detached in small flakes with the point of a pin; but in all the specimens examined by me, decomposition has taken place to such a degree as to leave no trace of organization. The material of the incrustation is so coarse that the interior does not afford a correct or fine cast or model of the vegetable, but in a few specimens faint impressions of a striated surface may be detected. The specimens are too short to enable me to determine whether the form of the tube corresponds with that of the plant upon which it is supposed to have been moulded; enlargements in the diameter may, however, be observed which probably mark the place of the joints. A more careful examination of more perfect specimens may enable Mr. Mackay to remove all doubts respecting the matter, and even to determine the species of equisetum from the general form and impression of the longitudinal grooves.

Mr. De la Beche, in his geological manual, alludes to similar incrustations, and quotes the following passage of Doctor Clarke Abel's voyage to China, as an example: "Singular cylindrical bodies resembling bleached bones are found in a bank of shell and sand east of Simonstown, Cape of Good Hope. On a closer examination many of them are found to be branched; and others are discovered rising through the soil and ramifying from a stem beneath, thicker than themselves. Their vegetable origin immediately suggests itself, and is confirmed by a further enquiry. They are seldom solid, their centres being either hollow or filled with a blackish granular substance, which in many specimens, except in color, resembles the substance called roestone by mineralogists. Their outer crust is chiefly composed of a large proportion of sand and a small proportion of calcareous matter, and in many specimens contains fragments of iron-stone, and quartz, an inch square. That they are really incrustations formed on vegetables which have afterwards decayed, is proved by the different degrees of change which the internal parts of different specimens have undergone. In some the organization of the plant sufficiently remains to leave its nature unequivocal; and near the sea the very commencement of the process of incrustation may be witnessed on the large fuci which strew the shore."

To these instances of simple incrustation, examples of complete impregnation of recent vegetable products with calcareous matter may be advantageously added. The following is an extract from the article, 'Organic Remains,' in the Edinburgh Encyclopedia. "By far the most remarkable instance of calcareous wood that has been produced, is that discovered by Collins in New South Wales. On a sandy spot, a hundred feet above the level of the sea, he found a quantity of broken branches of dead trees of two or three inches in diameter, intermixed with stumps of similar size, standing in an erect position, and shooting their roots into the soil. They were extremely brittle: and on being broken, the various structures of the wood were quite discernible. The exterior part resembled a calcareous sand-stone, and in some the interior was like chalk. The wood was partially preserved in some of the specimens; but in others it had entirely vanished. This appearance is very inexplicable; but a fact somewhat analogous was observed near Farringdon in Berkshire, where part of the root of a living elm was thus found partially covered and penetrated with a calcareous incrustation." It is obvious that analogous examples might be multiplied, but the present memorandum has already exceeded its just limits.

NOTICE OF SOME REMARKABLE APPEARANCES OF THE GRANITE, TO THE SOUTH OF DUBLIN.

BY THE REV. H. LLOYD, F.T.C.D., M.R.I.A.

(Read November 13, 1833.)

In the course of the last summer my attention was directed by Mr. Sharp, a Member of this Society, to a remarkable configuration in the granite, where it has been lately exposed to view on part of the line traversed by the Kingstown rail-road. The anomalous character of the rock exhibited at one point of this line, seems well worthy of attention; and as it may not have fallen under the observation of some of the Members here present, I venture to offer the following brief notice of the facts, in the hope that it may lead to a more extended inquiry on the part of others better qualified to form a judgment upon them.

The first appearance of the granite in the direction of the coast, occurs on the shore opposite to the village of Black-rock. The rock which appears in this place is of a rather singular character. It is a distinct granitic conglomerate, composed of rounded masses of granite of various sizes. The cementing substance is also granite, and the compound rock is one of considerable hardness. It appears evidently to have been produced by the recomposition of water-worn masses, in the usual manner. It occurs only in one spot, and it is somewhat remarkable that this spot should be the first in which the granite exhibits itself on the surface. It is from this rock that the village is said to have taken its name.

The granite continues to appear at intervals, from this point, until it is finally raised distinctly to the surface, on the shore beyond Kingstown and in the Killiney hills. The most remarkable appearance which it presents along this line, occurs between Seapoint and Old Dunleary, and at the distance of about a quarter of a mile from the former place. The granite is here formed into large boulders, which are imbedded in a granite of a totally different description. These boulders are of a very considerable size, varying from five to twenty-five feet in length; and in their smooth surfaces and rounded forms, they resemble the detached and wave-worn blocks usually found upon a granite beach, or the transported masses which furnish such striking evidences of diluvial agency. The rock itself seems to contain the quartz, felspar, and mica, in nearly the common proportions. It is of the usual greyish-white colour of the Killiney granite, and is remarkably compact and close-grained. On the other hand, the rock in which these boulders are imbedded, is so friable, that in many parts it crumbles in the hand. It is of a brownish tinge ; and it is further distinguished from the rock of the imbedded boulders, by the circumstance that it possesses something approaching to a stratified structure, being easily detached in large masses with plane surfaces, like some of the rocks formed by deposition. This regularly-formed mass is surmounted by a bed of stiff clay, from fifteen to twenty feet in thickness.

The similarity of these boulders, which I have endeavoured to describe, to the water-worn masses in their immediate neighbourhood on the beach, naturally suggests the idea that they have a common origin, and that the rock which surrounds them is a deposit produced by the recomposition of the granite fragments, which have been separated by the mechanical action of the waters. This idea seems to be strengthened by the existence of the conglomerate to which I have already alluded, and which is evidently produced in this manner. On a more minute examination, however, this supposition seems untenable. The fragments which compose the surrounding mass are not of the rounded form which they would have acquired, if subjected to the continued action of the water before they were agglutinated. In fact, the rock does not appear to differ from ordinary granite in the crystalline appearance of its constituent particles.

The existence of granite in globular masses is not very uncommon,* and seems to furnish a new feature in the resemblance which has been traced between this rock and those of decided igneous origin. That granite and porphyry, the basaltic and trap-rocks, and the modern lavas, are all to be referred to a common origin, seems to be now little doubted ; and the tendency of the older trap and volcanic rocks to assume a globular form, is well known. A remarkable fact of this kind has been lately mentioned by Mr. Horner, in a paper on the Siebengebirge, read this year before the Geological Society of London. In this interesting volcanic region he observed trachytic tuff containing balls of trachyte of various kinds. He compares them to volcanic bombs, and states that they are quite distinct in character from any of the trachyte found *en masse*.

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* In the Notes on the Mineralogy of the Vicinity of Dublin, by the Rev. Walter Stephens, mention is made of a granitic block, found in the quarries at the foot of the Three-rock mountain, which, when split, disclosed a nucleus nearly globular ; the outer part, to a considerable thickness, coming off in the form of a shell or case. Similar appearances have been observed by Saussure in Switzerland, and in the island of Arran by Mr. Jameson. Mr. Bakewell, in his Geology, states, that the granite, in which such masses are imbedded, is generally of a much softer kind than the central nucleus.

But I must leave these facts to others better qualified to speculate upon them. I only regret that the opportunity of observing them is now in a great measure lost. The granite boulders being of so much more firm material, have been invariably broken up to be employed in the construction of the pitching and other important parts of the works. On a late visit to the spot, I could not discover any of this species of rock remaining *in situ*, with the exception of a large imbedded mass which had not assumed the rounded form. The exterior shape of the boulders, however, may still be seen in many of the fragments; and the form of the cavity, occupied by one of them in the surrounding rock, is still distinctly preserved. Not far from this spot the granite is found in some places in a rapidly disintegrating state, owing to the decomposition of the felspar; and thin layers of porcelain clay may be observed at different places. It might be worth while to examine, chemically, whether the felspar exists in equal abundance in the surrounding rock as in the imbedded boulders; and if not, to consider whether that circumstance may not afford a clue to the explanation of many of the observed appearances.

ON THE GEOLOGY OF THE DISTRICT OF THE KNOCKMAHON MINES, IN THE COUNTY OF WATERFORD.

BY J. HODGSON HOLDSWORTH, F. G. S. L.

(Read November 13, 1833.)

Having been requested to lay before the Geological Society of Dublin a statement of facts, in relation to some Geological specimens collected by me during a visit to the Knockmahon Mines in the county of Waterford, (recently placed under the management of my friend, Mr. Petherick,) I will venture to do so, premising only that as the state of my health has precluded me from following up my researches to the extent I could have wished, the present must be considered merely a sketch (to be hereafter filled up) of a district abounding in points of interest, and deserving of accurate and scientific investigation.

The district of the Knockmahon Mines is situated on the sea coast, close to the village of Bonmahon, about seven miles from the base of the Monovoulagh, otherwise Commeragh mountains, and between the bay of Dungarvon on the west, and the bay of Tramore on the east. It appears to have been known from time immemorial as containing rich mineral deposits, very many of the metalliferous veins having been worked either by the ancient inhabitants of the country, or by foreigners. One rock in particular, only joined by a small neck of land to the sea cliffs, is perforated throughout like a rabbit warren, and bears the name of "Dane's Island;" for to a people so designated, all the old workings are by popular report attributed. That some race in an early stage of civilization explored the metallic veins of this district, is evidenced by the occasional discovery of stone hammers among the abandoned workings. These workings they could carry on with comparative ease, for all the metalliferous veins explored by them, opened out upon the cliffs of the coast, and the extent of their operations appears to have been confined to following the lodes as far as it could be done with ease, abandoning them in all probability, when obstructed by the influx of water or other accidental circumstances, or when they became unproductive.*

Within the compass of three miles, on the line of sea coast, (taking the village of Bonmahon as the centre) a considerable number of lodes both of lead and copper are distinguishable in the cliffs, some of considerable width, but others comparatively small. The direction of the principal lodes is about twenty degrees south of east, but from this direction others vary considerably. The principal lodes dip towards the north, though others vary as much in this respect as in their horizontal direction. The most productive lodes at present in course of working occur in slate rock. They sometimes pass through a siliceous rock, bearing a near affinity to hornstone, and the principal lode is in one instance split (technically "forked") by a rock,† in which a steatitic substance, probably serpentine, is disseminated, the general appearance being that of ophite.

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* With this crude statement I send a copy of part of Larkin's large map of Waterford, on which I have attempted to lay down part of the formations subsequently noticed. The map is, however, so very inaccurate in the delineation of *the hills and valleys* as to be of little use, and many places are wholly omitted.—See plate.

† My friend, Dr. A. Smith, has furnished me with the following characteristics of the steatic substance :—" It is infusible per se, but fused with borax, gives a lightish green globule very similar to serpentine under the same circumstances. The green substance imbedded yields to the knife,, is translucent, and gives a white streak."

The strata along the line of sea-coast before mentioned vary much in appearance, but in their constituents many of them approximate more closely than might be at first supposed. In addition to those subsequently noticed individually, I may mention chloritic rocks passing into chloritic slate, with occasional veins of fine earthy chlorite, accompanied by lamellar calc-spar, and prismatic quartz;—and a coarse splintery kind of horn-stone, though not of common occurrence. In connection with this last rock, I found traces of cobalt, viz. the blue and red earthy arseniate, and earthy black oxide of cobalt. In one small bay, west of Bonmahon, I found thin veins of asbestus in a siliceous slate, and thin veins of jasper of yellowish and reddish hues. Small cubes of sulphuret of iron, and also arsenical iron occur in the rocks of the coast: the former are very abundant and generally diffused. The lead lodes are not now worked, and do not appear to have ever been of great value or extent; they consisted (judging from fragments found) of the sulphuret of lead accompanied by calc-spar. The copper lodes consist of quartz, and produce native copper, sulphuret of copper, grey copper ore, and black oxide of copper; sulphuret of zinc, carbonate of iron, and sulphate of barytes also occasionally occur, and more rarely argentiferous sulphuret of lead. These metals and earths are generally found massive, and do not afford any of those crystalline specimens so valued by collectors. I ought, however, to except the native copper which is found disseminated in crystalline plates, and was formerly found capillary and dendritic. The quartz occurs very commonly in globular forms, the crystals being closely aggregated and diverging from the centre of the mass. In one of the workings I found a thin vein of lamellar carbonate of lime of a rose colour; and on clay-slate in another place, small, but highly splendent crystals of sulphate of lime. Pseudomorphous quartz sometimes occurs, having apparently been formed on cubical crystals of iron pyrites larger than any now found in the works going on.

I will now endeavour to notice some of the more remarkable rocks which I examined, beginning with those on the east side of the small bay in which the village of Bonmahon stands, and thence proceeding eastwards towards Tramore.

In tracing the Knockmahon sea-cliffs, in the compass of little more than a mile I found the following series of rocks, reckoning them from west to east. I would observe, however, that the cliffs along the coast have evidently yielded very considerably to the action of the waves, some of those about to be noticed being now partially covered at high water, and all of them washed by the surf whenever the wind sets in shore. At low water the rocks to a considerable extent are left bare; but are so water-worn, and covered by sea-weed, and shell-fish, as generally to render it difficult to trace them, except where a peculiarity in their external form appears.

1. A quartziferous porphyry.*
2. A species of chloritous clay-slate.
3. A copper lode.
4. A thin stratum of rock filled with organic remains.
5. A schistose rock.
6. Slate rock containing organic remains.
7. A schistose rock.
8. A columnar rock.

In the absence of the true criterion, (I mean chemical analysis) I find it extremely difficult to give a satisfactory nomenclature to some of these rocks. I thought at one time that they might be safely arranged with trap rocks: more careful examination with a powerful glass, has satisfied me that neither hornblende nor augite can be found in a visible form; but it is possible they may be classed amongst the petrosiliceous members of that family. The chemist may ascertain that which the assistance of the magnifier was unable to do. Chlorite is, I suspect, the colouring matter.

The rock first mentioned consists of small crystals of flesh-coloured felspar and of quartz, embedded in a paste which I imagine to be essentially aluminous; with the aid of a powerful glass, minute cubes of iron pyrites are seen, which, with the felspar and quartz, are the only crystalline substances. This formation is rather extensive on the line of coast to the east of Bonmahon bay, and is also found cropping out on the sides of several low ranges of hills, and even attaining a considerable altitude in more than one place inland: in the latter cases it becomes more silicified, but still retains its porphyritic character. Thus it occurs in a valley near the mines, called *Ballyristane*, where it is laid bare in cutting a water-course for the use of the mines,† but it is not discoverable on the opposite side of the hill as far as I could perceive. It occurs again rising into gentle eminences in several places along the line of road from Bonmahon to Kilmacthomas, which runs nearly north and south:—viz. at *Ballankine*, a little to the west of the road, and about a mile from Bonmahon:—from Ballanhine it may be traced across the country as far to the north-west as *Bennan* (or *Brenain)-hill:* the same rock appears to the right and left of the road to Kilmacthomas in three places, called *Carrick Castle Hills*—at the bottom of the highest of which a quarry was opened, which shows that it there rests upon a fine grained black slate.

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* Characteristics ascertained by Dr. A. Smith:—1. Does not effervesce with muriatic acid. 2. Scratches glass with difficulty. 3. Gives fire with steel. 4. Before the blow-pipe becomes glazed on the surface, but only fuses partially. 5. The imbedding paste scratches easily. 6. Streak white.

† Vide the lower water-course marked out on the map.

The same formation is also found near to the north-east angle of the Monovoulagh mountains. It has been before observed, that many isolated hills extend from that portion of the mountain range in an irregular direction towards Tramore. One of these hills, called by the peasants, *Cruachaune*, (in the map spelled Crougban,) which lies very near the mountains, rises to a height little short of a thousand feet, and assumes a conical form. It stands between the roads which run from Kilmacthomas in a north-east direction to Carrick, and easterly to Waterford. I send a specimen from this hill, at the base of which, and separating it from the conglomerate of the mountain range, clay slate occurs. I suspect that a considerable portion of the range of hills which runs in a nearly north-west and south-east direction from the hill of Cruachaune towards Tramore, will prove to be of the same formation. It is visible on the road near Tramore, and appears in the sea-cliffs which I examined, from Tramore westward to Annstown. A more careful survey will, I think, ascertain it to run in two nearly parallel ridges across the country, nearly north-west and south-east, and that in some places (particularly towards Tramore) it passes into a species of compact felspar, which is evidenced by its white coating under exposure to the atmosphere.

I have noticed clay-slate as occurring in the valley between the Monovoulagh mountains, and the hill of Cruachaune. The same formation occurs at and around the town of *Kilmacthomas*, and again appears near Strabelly, and continues to the east side of Dungarvon bay, where limestone occurs. At Strabelly, the clay-slate formation is of considerable extent, and in this part the base of the Monovoulagh mountains approaches close upon it. It lies in a highly inclined position, and in places is nearly vertical. On the east side, (towards Bonmahon) it passes into chloritous slate, and a lamellar siliceous porphyry. On the west, (towards Dungarvon) it joins the limestone which appears rather abundant round that place. It contains organic remains, and is highly fetid when struck. Several quarries were examined, and the limestone was found rising nearly to the surface. They are not, however, worked to any great depth, probably because they are scarcely above the sea level, to which they lie very near. Those examined were to the north and east sides of the bay.

In noticing the rocks, (numbered 4 and 6 in the series,) as occurring on the line of coast, I have only to call attention to the organic remains found therein; for the composition of the rocks is, I believe, the same, viz. a variety of clay-slate, or probably a greywacké. The rock (No. 4,) is found occurring in the close neighbourhood of a fine lode of copper, if indeed the term rock can be properly applied to that which is but a thin seam running up the perpendicular face of a rock, exposed in the course of mining operations, and running inland only a few yards. It is in a state of great disintegration from the oxide of iron which pervades it; and perhaps also in part from its proximity to a metalliferous vein. It splits readily into short joints, and then exposes the organic remains imbedded in it, and which are found covered with an ochreous paste extremely soft and greasy to the touch. Trilobites, and I understand casts of a species of terrebratula are very distinct. The slaty rock is of small extent in width or height, and does not appear to extend to any great depth below the surface. Neither have organic remains been found in any of the excavations for mining purposes carried on near the place where they occur. In the rock, (No. 6,) the organic remains are thinly scattered through the rock, or found in a series of thin horizontal beds, separated from each other by intervening portions of the rock itself. The Madrepores form the thickest of the beds, though they do not exceed four or five inches—the thinner beds are rather layers, of from one to two inches, and generally contain only shells and corallines. This rock being exposed to the action of every high tide, is deeply worn externally, and thereby the beds of fossil remains are exposed, for they appear to be less affected than the rock. Thus the Madrepores, &c. are found protruding from the face of the rock, and it would appear that they are but loosely imbedded, for a slight blow dislodges them from the rock; the latter is, nevertheless, of a very tough texture, rendering it difficult to procure good specimens of a cabinet size.

About two hundred yards from the schistose rock, last described, (No. 6, of the Series,) and separated from it by other schistose rocks of various degrees of compactness, and more or less lamellar, (which are, however, free from all organic remains,) a formation occurs, to which I can give no other descriptive name than that of columnar trap. The regularity of this formation is highly interesting, and the correctness with which the columns fit, nearly approaches that of the finest basalt, and must forcibly strike the most superficial observer. The columns vary considerably in size, and sometimes in the number of their sides. Occasionally one column has a concave form on one side, which is found to fit closely into the convex side of that which adjoins. Sometimes they occur marked with three or four grooves, which fit into corresponding projections. The columns are generally perpendicular, but a few may be found leaning towards the east, and others have assumed a slightly curvilinear form. This formation rests on the schistose rocks of the district, and must once have extended southward to a considerable distance; for though covered with shell-fish and sea-weed, it may, from the regularity of its form, be traced running into the sea even beyond low water mark of the lowest tides.*

I conceive this formation to have been once far more extensively visible along the line of coast in this place. It may be traced, however, at a short distance further to the east from Bonmahon, and though externally much less perfect in form, is probably of the same period of creation. In this latter case it caps a high cliff to its very summit, but does not extend more than fifty feet in depth. It rests upon rocks which cannot be accurately defined, owing to their extreme state of decomposition, which probably arises from their continuity to a metalliferous vein which has been anciently worked by seven levels driven into the cliff, one above another,—the uppermost one being actually driven through the columnar trap, there capping the cliff. This metalliferous vein is known by the name of the "Seven Drift Course." This lode may be traced inland by the old workings for the distance of half a mile; and at that distance, among the refuse lying around an old shaft, called *Bawnaghiva*, various organic remains were found, which I believe possess no common interest.† The circumstance of trilobites, terrabratulæ, entrochi, corallines, and madrepores being found in close proximity to a metalliferous vein, and in a rock of no common character, cannot fail to excite attention: but the merit of the discovery is due to Mr. Weaver. The lode itself runs inland through a slightly raised hill, which is highest towards, and in fact forms, the sea-cliff; it falls into, and forms one side of a gentle valley, close to which is the shaft where these organic remains occur. Diligent search was made at two other shafts, which occur between Bawnaghiva shaft and the sea-cliff, for organic remains, but without effect; and a similar search among the rocks of the coast round the Seven Drift Course, was equally without success. Near the base of the Seven Drift Course, an amygdaloidal rock in small quantity was found, and also a finely contorted soft kind of black schist.

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* Characteristics of the "Columnar Trap," furnished by Dr. A. Smith:— 1. Specific gravity, 2,662. 2. Translucent on the edge. 3. Scratches glass feebly. 4. Yields with difficulty to the knife. 5. Streak white. 6. Gives sparks with steel. 7. Not affected by dilute muriatic acid. 8. Infusible per se. 9. Fuses partially with borax. 10. With carbonate of potash, it melts into a pale green vesicular bead.

† I found one, and only one, specimen of a species of helix, and one having much the appearance of a belemnite, which are in my private collection.

I know not whether Mr. Weaver discovered the trilobite in another locality, and from what I heard on the spot, I believe its occurrence was not known till I happened to find it. The rock† in which it is found may be considered as a compact chloritic aluminous schist, varying in no real degree from other rocks of the schistose sort on the coast. The organic remains in it are very sparingly disseminated towards the surface, and are only occasionally found. It either overlies, or is cut through by one of the conglomerate dykes subsequently mentioned; the former is, I believe, the case.

On the east side of the valley of Bonmahon, which runs from the sea to nearly the foot of the Monovoulagh mountains, a water-course has been cut which intersects several chloritic schist rocks, passing from the slaty to the massive structure, and of various degrees of compactness. At a short distance from these in the same valley, but nearer the sea, a schistose rock occurs, containing rounded nodules, which may, I presume, be considered as greywaché slate. It is on the opposite side of the range so forming the east side of Bonmahon valley, that the valley of Ballyristane lies, where the porphyritic felspar rock occurs, as before stated, though the rest of the rocks in Ballyristane valley, agree in general character with those before noticed in Bonmahon valley. About a mile up Ballyristane, a quarry has been opened, where the formation is a compact rock of a slaty structure lying in a highly inclined position, sometimes passing into a very fibrous texture in thin seams, and probably containing magnesia.

I will now offer the result of a few observations made in the neighbourhood of Tramore.

At West Town End, one mile from that place, the porphyritic felspar rock is found cropping out at the surface; and within a few hundred yards of it a rock approaching closely, if not identical with compact felspar, runs from S. S. W. to N. N. E. I examined the rocks of the sea-coast for several miles westward from Tramore headland, towards Annstown. At *Garririsk*, the arrangement was as follows: at the bottom a bluish siliceous schist, above which occasionally appeared a dark-coloured carbonaceous shivery slate, but never to any great extent; and above this, incumbent on it, or on the blue schist, as the case might be, the siliceous or compact felspar rock, found at West Town End. In many places this rock is highly coloured by oxide of iron, and assumes the appearance of a coarse jaspery rock. This formation extends as far as the islands of Kam or Ikean, where it is cut off by a long series of rocks of the most compound and heterogeneous character and nature, which run for several miles along the coast beyond *Kilpharicey*. Occasionally the blue schist rises up for an inconsiderable height, and evidently underlies the whole formation. Masses of the compact felspar, or siliceous rock, also rise up; and fragments of it, and also of the carbonaceous slate are found embedded in the extended formation before mentioned, which has all the appearance of a steatitic rock. It is occasionally rendered porphyritic by the crystals of felspar embedded in it, and may probably be referred to the ophites. The whole formation indeed merits far greater and more careful examination than I could at the present give it.

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† "This is only fusible by intense heat, and gives a grey opaque bead.. It contains iron in considerable quantity, without any trace of lime."—Dr. A. Smith.

At Kilpharicey and its neighbourhood, the surface is covered with rounded stones which I should designate chert, were they not invariably covered by that white coating, so characteristic of compact felspar when under the influence of the atmosphere. To my surprise I found many of them containing organic remains similar to the chertzose rocks of Derbyshire.

I shall now proceed to notice the great conglomerate formation, in which I shall so far differ from Mr. Weaver,—that as he considers the sandstone to be the prevailing, and the conglomerate the occasional form in which its strata appear, I have found the conglomerate structure greatly to preponderate.

The direction of the Monovoulagh mountains, is nearly south-west to north-east. The south-west end curves round towards Dungarvon bay, and forms the lower portion of the range, whilst towards the north-east they attain an elevation of about 2500 feet. At the foot of the north-east end of these mountains, runs a narrow but deep valley, the opposite side of which is formed by a range of high ground which opens off in several places towards the sea-coast,—forming the commencement of several valleys which debouch towards the sea, and through which the river Mahon and other streams, having their sources in the mountains, take their way. Towards the north-east end, are several isolated outlying hills of considerable elevation, which trend towards the bay of Tramore ; so that in fact the mountain range, taken in connection with these outlying hills, when viewed from a distance, appears to form nearly the segment of a circle, one end approaching the sea at Dungarvon, and the other near Tramore.

In various places along the line of sea-coast, between Dungarvon and Annstown, and more particularly around Bonmahon, the conglomerate formation is exposed to sight; I examined several of them, but there are others to which I could not get convenient access. In a bay between Strabelly and Bonmahon, called *Ballyduan*, I had full opportunity to examine it: the conglomerate lies here in an inclined position, but does not attain any great height, and has more the appearance of a conformable rock than in any other place I examined. The extent of this formation in this spot, is but small, but a red micaceous sandstone slate, which is generally found accompanying it, (where it crops out on the sea-coast), is very extensive, and rises into cliffs, upwards of two hundred feet high. This formation may be traced inland for upwards of a mile in a north westerly direction: it is, however, overlaid, I believe, by the porphyritic felspar rocks at Brennan, or Brennan-hill.

In another, though smaller, and almost inaccessible bay, closely adjacent to the last named, but nearer to Bonmahon, called *Cuineennacarthen*, (Forge Bay), the conglomerate appears bounded on each side by the common rocks of the coast: but the conglomerate is here distinctly separated, by a vein of quartz, from the red micaceous sandstone slate. Here both these rocks rise perpendicularly side by side, and may be traced running out into the sea,—which is not ascertainable so distinctly at the bay of Balyduan, in consequence of the fine sand thrown up in such abundance as to be carried away for agricultural purposes.

In another place near the bay of Bonmahon, the conglomerate forms a bold, though short headland, and is known by the name of Kennedy's Island. It rises out of the sea-beach to the height of one hundred and twenty feet, and runs inland from south-west to north-east: it is partially covered by every tide, but at low water is accessible in every direction. It consists of coarse conglomerate, fine grained conglomerate, the red sandstone slate, (which sometimes passes into the fine grey slate which occurs abundantly in some of the conglomerate of the Monovoulagh range,) and a coarse sandstone with ferruginous marks. The whole of these rise side by side, nearly perpendicularly from the sea-beach.

The red sandstone slate in this place, sometimes passes, by almost imperceptible gradations, into the fine conglomerate; in other instances it is strongly marked in the transition. The direction of this rock may at low water be traced into the sea for a considerable distance. It has there yielded to the action of the water, whilst masses of the aluminous and slaty rocks near it, rise out of the sea above the level of the highest tides. I cannot, however, help thinking that this headland was once bounded on each side by the common rocks of the coast, though they must have long since yielded to the action of the waves,—to which action I believe them to have been rendered more accessible by the influence of metalliferous veins, and a dislocation which had its origin when the conglomerate rock itself was first formed in its present shape.

On the eastern side of the bay of Bonmahon, the conglomerate with the red slate, appears, but underlying the rocks of the coast. It runs nearly south-east and north-west, and it is thought that it disrupts the principal lode, or as the miners say, "heaves the lode." The same formation occurs also within the scope of the mines in long but slight elevations running inland. As far as it has been here explored in depth, it appears to be incumbent upon the slate formation. In the course of sinking a shaft in the mines, the conglomerate was cut through at the depth of about ten fathoms; in that place it was accompanied by the red sandstone slate, and also by ferruginous sandstone, as in the rock called Kennedy's Island; *and these two are the only instances in which I discovered any sandstone.* When compared with the conglomerate, or any other rock around it, the amount is so trifling, that its existence might have been passed over without any very serious impeachment of one's accuracy.

Between the mines and Ann's-town, I could not discover any traces of the conglomerate, and from Ann's-town to Tramore, the rocks are essentially different, as I have already attempted to show.

About four miles from Kilmacthomas, on the road to Portlaw, and seven from the Monovoulagh range, I found (in a quarry by the road side,) the junction of clay slate and the conglomerate, very distinctly marked. The slate was thrown up nearly perpendicular.

Of the interior of the Curraghmore park and domain, I cannot speak, but in several places around it, traces of the conglomerate formation were distinctly visible.

In all these instances, I consider the conglomerate as identical with that of the Monovoulagh mountains, the source and origin of its formation and elevation being one and the same:

I therefore now propose to describe it as I found it existing in the Monovoulagh range.

On proceeding from the town of Kilmacthomas, towards the lake of Coumshenane, (in the map which accompanies this statement, called Coumshingoun), the clay-slate was at first the only rock visible; but when within about four miles of the foot of the mountain range, I found the entire face of the country covered by the conglomerate in blocks, varying from a small size to masses of the greatest dimensions. Every step I advanced from this place, till the summit of the range was attained, showed the uniform and unvarying character of the rock, and left no doubt as to its identity, or of the fact that the whole body of the mountain range was essentially composed of it.

The lake of Coumshenane, situate at a height of nearly 1500 feet, is of nearly an oval form, lying north by west, and south by east. At the northern end rises a perpendicular precipice to the height of more than a thousand feet: on the eastern and western sides the rocks are but of little less altitude, though they are not quite so precipitous. At the southern end, however, the entire of the rock to the level of the lake has been carried away, and the surplus waters of the lake, (now fed by the melting snows or bursting clouds) there find an outlet. The statements of the residents in the valley are, that the lake is as deep as the precipice which overhangs it, though some are content with stating that it has been sounded with a line of fifty fathoms. Be that as it may, there can be little doubt that it is of very great depth, and the rapid shelving of its banks within two feet of its brink, is at an angle which verges closely upon sixty degrees. The precipices which on three sides surround this lake, are from top to bottom conglomerate, identical with that found on the sea-coast. It is scarcely possible for any one to stand at the foot of the lofty precipice at the northern end of the lake, and direct his sight to the opposite extremity, without feeling that he is on the brink of that which bears the strongest resemblance to the crater of an ancient volcano. The towering precipice at his back,—the abrupt termination of the side rocks where they have just reached the southern end of the lake,—the masses which at that end are scattered on the margin, and over which the eye glances till it rests upon the tops of the intervening hills, and ultimately takes in a large extent of the distant ocean,—all form a scene which speaks in the strongest terms of some grand convulsion of nature, which carried away before it the southern side, and threw for miles around the fragments of the enormous mass which it broke up and dislodged.

I have now only further to observe, that this mountain range was examined in several places along its line, and was found to consist from top to bottom throughout its course, of conglomerate without any trace of sandstone, and in no degree did it appear as a conformable rock. True quartz veins intersect this formation in places, and I found occasionally in these veins, beautiful groups of that variety of quartz called rock crystal, accompanied by specular iron. In the accompanying copy of part of Larkin's map, I have laid down as correctly as I can, the extent of the formation *actually investigated.* That it is greatly more extensive, I am confident; but as I have throughout sought to avoid exaggeration, I have rather diminished than extended the designation of the part so investigated.

Two miles to the north-west of the city of Waterford, there occurs a true *sandstone* alternating with the conglomerate; which latter rock, however, I believe to be distinguishable from the conglomerate of the Monovoulagh range:—I mean as being a more recent formation, and one which is identical with the conglomerate around Dunmore.

The great thickness of the conglomerate does not lessen the interest which attaches to the elevation of so great a mass of a rock, distinctly of mechanical origin, above the existing level of the lower country; and we may well inquire whether the mountain chain of the Monovoulaghs, and the detached dyke-like masses found along the coast, have been contemporaneously raised to their present level,—not overlooking their contiguity to a columnar rock, generally admitted to be of igneous origin, nor the elevation of strata containing marine organic remains of the oldest formation.

There is also another effect produced within the near neighbourhood of these pseudo-dykes, well meriting attention in reference to this point; I allude to the dislocation of the metalliferous veins (and of the rocks through which they run,) which occurs to an almost unparalleled extent in the mining district of Knockmahon.

Wild conjecture and theoretical prejudice may on these points find ample scope for riot: but facts carefully ascertained, and deductions accurately wrought out, can alone satisfy the true Geologist. My regret is, that circumstances precluded me from doing more towards elucidating them: and influenced by this feeling, I shall be thankful to any gentleman who will favour me with abstract points of inquiry, to which my attention shall be directed, during a second visit I am about to pay to the district of the mines.

List of Specimens illustrative of the Geology of the District around the Knockmahon Mines, in the County of Waterford.

Limestone formation.

Limestone (secondary) from Dungarvon.

Clay-Slate Formation.

Clay-slate from Strabelly on the road from Waterford to Dungarvon.

Clay-slate from a valley at the foot of the Monovoulagh mountains, and of a hill called Cruachaune.

Clay-slate from the neighbourhood of Kilmacthomas.

Chloritic Clay-Slate, &c.

From the east side of Bonmahon bay. This rock contains trilobites and a species of zoophyte.

Various specimens from an old shaft called Bawnaghiva, more or less disintregated and partially arranged with reference to its supposed contiguity to a metalliferous vein, and to its organic contents,—which consist of casts of trilobites, terrebratulæ, &c., and of corallines.

Do. from a decomposing rock closely adjacent to a metalliferous vein—contains shells, &c.

Do. from a compact schistose rock—contains bivalves, and a variety of madrepore.

Do. from the copper-mine called Ballinisla.

Do. (containing a steatitic substance) from same.

Do. which underlies the steatitic rocks near Tramore.

Do. from a quarry in a valley called Ballyristane, near Bonmahon.

Series of rocks from the valley of Bonmahon.

Conglomerate Formation.—Sometimes accompanied by Sandstone.

Conglomerate from a quarry between Kilmacthomas and Portlaw, on the junction of the conglomerate with clay-slate.

Conglomerate from a quarry, two miles north-west of the city of Waterford. Sandstone interstratifying with this.

Conglomerate from the Monovoulagh mountains, where they trend off towards Carrick.

Do. from the Dalligan rocks, part of the Monovoulagh range.

Do. from Cuttean, another part of the same range.

Do. from the lake and precipice of Coumshenane, in the Monovoulagh mountains.

Do. from the Knockmahon mines. Sandstone found accompanying in this place.

A conglomerate cut through in working a lode forming part of "the Seven Drift Course."

Columnar Trap, and its accompanying Rocks.

Columnar trap from the Knockmahon cliffs.

Amygdaloidal and slaty rocks from the foot of a rock called the "Seven Drift Course," which is capped by columnar trap.

Steatitic Formation.

From the sea-cliffs near Ikean or Kean island, near Tramore. Sometimes becomes porphyritic.

Quartzose Rocks passing into Chert, and thence to a species of Compact Felspar.

A quartzose and a porphyritic quartzose rock, containing felspar, from West Town End, near Tramore.

A chert (or felspathic rock) containing organic remains.

Porphyritic Rocks.

From the Knockmahon cliffs.

Do. (fragments of slate imbedded ?)

Do. from the valley of Ballyristane.

Do. from Carrick-castle Hills, black slate underlying.

Do, from the hill called Cruachaune.

ACCOUNT OF THE LANDSLIP WHICH RECENTLY TOOK PLACE NEAR LARNE, IN THE COUNTY OF ANTRIM.

BY JAMES M'ADAM, ESQ.

(Read March 12, 1834.)

About a mile, south of *Larne*, in the county of Antrim, at a place called the Bank, a singular landslip took place in the month of January, 1834. The west side of Larne lough is bounded by one of those mural escarpments of rocks, so peculiar to the Antrim coast. The summit stratum is basalt, overlying chalk and green sand, under which a stiff blue clay crops out, extending for several hundred yards beyond the escarpment. This is covered with debris from the rocks above, forming a talus, and being the vegetable soil. This talus has a considerable angle, and is bounded by the road, which is so close to the water, that for a short way, and at the place where the slip was greatest, it merely separates the talus from the beach.

On the evening of the 17th January, there was a slight appearance of motion in the ground, and during the night a line of barns was completely destroyed, the northern boundary of the slip passing through them. The motion continued for two or three days; and during that period it might have been at times perceived, by an observer regarding a fixed object, and comparing with it the position of any object or point in the slipping ground. At the termination of the event, the talus had completely altered its inclination, and from a very great slope it had fallen down into a nearly horizontal position. It appeared to be torn from the mural cliff, and afterwards left below, displaying, at the greatest dislocation, a fall of about twenty feet. From the upper part down to the beach, there was a total alteration of the surface, former elevations having been depressed, and hollows having been raised up. At the highest point the ground had not slipped very far, perhaps a fall of four feet being the extent of the depression; but this sinking increased towards its northern extremity, where the fall had been greatest. Between the cliff and the road there had been a great number of parallel, or rather concentric rents, of trifling depth. These were very numerous in the middle of the ground. A narrow road running through these rents to a quarry in the cliffs, was very much dislocated, and the chalk gravel, of which it was composed, was so loosened that the road seemed as if artificially broken up.

At the southern end of the slip there is a remarkable depression; a part of the ground, about six or eight feet wide, having fallen down about four feet, leaving a perpendicular bank on each side; but with the exception of this, the disturbance at the southern end is very trifling. The great dislocation is towards the northern boundary; and it is fully exemplified in the alteration of the highway, which has been shifted nearly twenty feet from its position at the barns, which were shattered, as mentioned before. It is evident that the upper part of the mass having pressed, by its fall, upon the lower, a crushing or squeezing of the ground, next the road, took place; this squeezing not only pushed the road nearer to the beach, but it also raised it up; and the lateral weight or pressure increasing as the slip advanced, the beach became the most affected of all the parts of the ground. Here the squeezing was so great, that a bank was formed at one place nearly twenty feet high, at which place the beach had been previously covered by the tide at high water. This bank resembled a wharf or quay, and could have been easily converted to that purpose by driving piles along its face, to prevent its materials being washed away by the action of the sea. The relative depth of the water was so increased that this was a matter of great practicability. Between this elevated beach and the highway there is a small hollow, like a pond, that has been caused by the accident; this has become filled with rain water. The road was so much affected at first, that it was quite impassable; the hedges were thrown out of their places, and the trees had their roots bared by the dislocation.

It is very difficult to decide upon the immediate cause of the slip, but it will be satisfactory to state the evidence the writer has obtained. For the entire length of the coast of Antrim, or to speak more correctly, along the continuous mural escarpment that bounds the basaltic area of the north of Ireland, there is a talus of debris formed from the materials that have fallen from the rocks above, and that have become more or less disintegrated by the action of the atmosphere and of torrents. This debris abuts against the escarpment, and from the high angle at which the slope is often observed, it is evident that a trifling force will suffice to alter the position of the mass, and cause it, by its gravity, to fall to a lower position; it is therefore evident, that in such an inclined plane the lower end will have a greater thickness than the upper. If the substratum of this debris be ever worn away, it is plain that the slope will alter its angle by the falling of the mass, and this mass being evidently thrown into smaller bounds by its change of inclination, the lower parts will be crushed or squeezed, and a consequent alteration of surface will ensue. The appearances at Larne sufficiently illustrate this. In the same neighbourhood trifling landslips have frequently occurred. In the construction of the new road from Larne to Glenarm, much annoyance is given to the workmen from the slipping of the ground. We may frequently observe along the flanks of the hills, traces of the superficial stratum having fallen from its originally inclined position, the rocks being often bared, as if their earthy covering had been violently torn from them. But the most singular illustration of the slipping of the ground in the neighbourhood of Larne, has been produced by artificial means, and is at the very extensive lime works of Ballyligg, near the upper end of the lough. The quarrying of the chalk at this place is on a very large scale, and an immense quantity of rubbish has consequently been taken out along with the more useful material; this rubbish has been thrown upon a field close to the shore, and is now become a heap or mound of considerable elevation. The substratum of the field is partly green sand and partly blue clay, and is consequently soft. The weight of the mass has pressed upon the centre and back part of the field, giving it a considerable depression, and it has squeezed the part next the beach in the same manner as at the great landslip, giving it a considerable elevation. In a similar manner, it has cracked a garden wall in its immediate vicinity. In fact, there is the most striking resemblance in the appearance of the two places.

It was stated at the commencement, that a line of barns had been shattered, the northern boundary of the slip passing through them. What is very singular, the foundation of these buildings was partly blue clay and partly gravel, and the fissure exactly coincided with their line of division. There was a dwelling house a few feet farther to the north, and this received no damage, its foundation being gravel; it was therefore at the junction of the blue clay and gravel the greatest effects of the landslip were visible. The extreme humidity of the past winter will be ever remembered; and the quantity of rain that fell in the neighbourhood of Larne, was, from its geographical position, very great. It is evident, that if it fell on gravel, it would percolate through it; but if it fell on vegetable mould lying on stiff blue clay, the effect would be very different. This clay is remarkable for resisting the passage of water through it, and is employed for the lining of dams, to prevent the escape of water. It is evident that the quantity of water accumulated in consequence of the rains of last winter, would pass through the superficial covering of mould as far as the blue clay, which would resist their further progress, but they would find no obstacle from the gravel, which would freely permit their passage. The solution of the question is thus brought within narrow limits, but the immediate cause has not as yet been brought to light. The quantity of ground affected is about eight acres.

ON THE NEWLY DISCOVERED CAVE SITUATE BETWEEN CAHER AND MITCHELSTOWN.

BY JAMES APJOHN, M.D. M.R.I.A., PROFESSOR OF CHEMISTRY IN THE ROYAL COLLEGE OF SURGEONS, IRELAND.

(Read March 12, 1834.)

Having spent some weeks in the south of Ireland, during the past autumn, and being in a great measure disengaged, I readily acceded to the proposition of my friend, Mr. Thomas Kearney, to whom I am indebted for the map which illustrates this paper, to accompany him in a visit to the limestone cave recently discovered in the County Tipperary, in the hope of encountering some appearances, the description of which would prove interesting to the members of this Society.

The cave in question is situate nearly midway between Caher and Mitchelstown, at about 150 yards to the left of the old road connecting these two places. But before proceeding to a description of it, it will be convenient to glance, cursorily, at the geological structure of the surrounding country.

The townland of Coolnagarranroe, in which the cave is found, lies in the valley which separates the Galtee and Knockmildown chains of mountains, the former constituting its northern, the latter its southern boundary. The prevailing rock at this extremity of the Galtees is conglomerate, which occasionally passes into sandstone, while that which composes the opposite chain of hills possesses a structure intermediate between that of sandstone and schist, and includes few, if any, rounded or water-worn pebbles. The material of the interposed valley is compact grey limestone, and this rock, in the townland already mentioned, forms two small, rounded hills, within both of which cavities of considerable magnitude exist. One of these, namely, that occurring in the western elevation, has been known from the remotest antiquity, and repeatedly explored; the other, which was only discovered on the 2d of last May, by a man of the name of Condon, while quarrying for stones, is that which has since attracted so much attention, and respecting which I purpose making a few observations.

The hill within which the newly discovered cave exists, rises to the height of about 100 feet above the Caher and Mitchelstown road; and the entrance to it, which is at the bottom of a quarry, is somewhat less than halfway up, or about 60 feet from the summit. The mouth of the adit is covered by an iron grating placed over it by a man of the name of Gorman, the occupier of the farm, and kept in its place by a hasp and padlock, with a view of preventing the descent of any but those who, by the payment of a small fee, acquire the right of visiting his subterranean wonders. Upon getting within the grating, a narrow passage, of about 4 feet in height and 33 in length, and sloping at an angle of about 30° with the horizon, terminates in an almost vertical precipice, 15 feet in depth, down which the visitor passes by means of a ladder. Advancing forward from the foot of the ladder, the floor resumes its original angle of inclination, which it maintains for the distance of about 28 feet. It now becomes nearly horizontal, and continues so for 242 feet, or until the opening into the lower middle cave is reached. The bearing, however, of this passage, which was hitherto due south, becomes, at 150 feet from the mouth of the middle cave, S. E. The height of the entrance varies a good deal, the limits being from 3 to 17 feet; its average breadth from the ladder to the point where the bearing takes a more easterly direction, is about 9, and from this point to the entrance of the cave, 27 feet. The floor, from the foot of the ladder forwards, is everywhere strewed with blocks of limestone; and the roof, which is very irregular, exhibits scarcely any sparry productions.

The lower middle cave, at which we have now arrived, is one of very considerable magnitude. In shape its ground plan resembles a mattrass or bottle, with cylindric neck and globular bottom, the diameter of the latter being 95, and the length and diameter of the former 72 and 42 feet respectively. The vertical section of its wider end is that of a dome or hemisphere, the apex of which has an elevation above its base of 35 feet. Stalactites of a small size depend from the roof, and a sheeting of sparry matter is observable all along the joints of the limestone, and covers beneath many parts of the floor, where it is usually superimposed upon a very fine red clay, which would appear to have been washed down by water filtering from above before the interstices of the arch were sufficiently closed by calcareous incrustations. The floor of this cave is strewed with large tetrahedral blocks of limestone.

From the southern extremity of the chamber just described, a passage, varying in height from 5 to 10, and in breadth from 7 to 14 feet, and 60 feet in length, leads to one of somewhat greater magnitude, and of much greater interest, which is known under the name of the upper middle cave. The horizontal section of this natural excavation may, neglecting its irregularities, be considered as a semiellipse, the axes of which are respectively 180 and 80 feet, the major pointing directly E. and W. A vertical view or section, corresponding to the line connecting the northern extremity of the minor and eastern extremity of the major axis, shows the roof nearly horizontal, and raised 20 feet above the floor. This is the most remarkable part of the entire cavern, for the magnitude, beauty, and varied and fantastic appearances of its sparry productions. Immediately upon entering the cave, on the right hand, and attached to the wall, is found the organ—a huge calcareous growth, which is conceived to bear some resemblance in shape to the musical instrument from which its name is borrowed. Nine great pillars of carbonate of lime occur in this same compartment, rising from the floor to the cieling; of these the lower third is usually of great diameter, and very irregular in form, while the remaining, or upper portion, usually exhibits the shape of an inverted cone, the base of which is in the cieling, while the vertex is in connexion with the lower portion of the pillar. In some instances I observed, (but am not sure that it was in this part of the cavern,) that the upper cone had not come in contact with the stalagmite below, though should the calcareous deposition proceed as heretofore, there can be no doubt that such junction will be finally achieved. The most remarkable pillars in this cave are those known among the guides under the names of *Drum* and *Pyramid,* the former of which occurs 15 feet south of the organ, the latter at the eastern end of the chamber. The base of the former is not simple, but composed of stalks cemented together, and having leaved or foliated edges; some of these edges are of great extent and thinness, and when struck gently, vibrate so as to produce an agreeable sound. The Pyramid, a pillar 14 feet in height, rests upon a base of great dimensions, and its shaft is distinguished by the circumstance of its tapering upwards towards the cieling. The other pillars are of inferior size, but some of them possess a symmetry and beauty superior to those just described. In addition to the pillars, stalactites and stalagmites every where abound; the former depending from the roof, the latter springing from the floor of the cavern. They are of every length, from an inch to 3 or 4 feet; and they, or rather the greater number of them, together with the pillars, usually correspond in position to the vertical joints of the limestone beds composing the roof of the chamber. Before leaving this part of the cavern, I should not omit to mention that S.S.W. from the *Pyramid*, and at the distance of 20 feet, there is a rectangular sparry production, raised some feet above the floor, to which, from its shape, the name of *Table*, has been applied.

From the upper middle cave there are two exits beside that already mentioned, one of which takes an easterly, the other a southerly direction. The former, which augments gradually from 4 to 15 feet in breadth, terminates, at the distance of 110 feet, in a cul de sac; but about 20 feet from this extremity, there is sent off, in a northern direction, an arm which conducts to the cellar cave, and what is called the *river*. When visited by us this *river*, which is very difficult of access, appeared to be but a stagnant pool; (or, if the water is ever in motion, such phenomenon was not at the time to be observed;) in the winter season, however, there can be little doubt, as shall be hereafter shown, that this, as well as several other parts of the cavern, is subjected to the action of running water.

The southern exit conducts, by a steep and rugged passage about 50 feet in length, first ascending, then descending, to what is called the *long* cave—a designation calculated to convey erroneous notions respecting the nature of this part of the cavern. In point of fact, it consists of several galleries, two of which pursue an E.N.E. and W.S.W. direction, and are intersected by several others at an angle of about 105°, or as nearly as possible that of the primitive crystal of carbonate of lime. The east and west galleries average a width of about 14 feet, and have, the one a length of 190, the other of about 350 feet. Of the cross galleries, which are all exactly parallel to each other, and have a direction N.N.W. and S.S.E., the largest is that which faces the entrance from the upper middle cave, and may be considered a prolongation of it; its breadth is 14, and its length about 140 feet. The second possesses the same length, but its continuity is interrupted, the entire of the interval between the lanes it intersects not being traversed by it. It extends somewhat further south, and sends off to the west two branches of about 38 feet in length. Two other galaries, having the same direction with these, are so small, that by the careless observer they may be considered as fissures, and they are so marked upon the map. Throughout the entire of these passages, the fine red clay already described as occurring in the lower middle cave, is very abundant, and in many places is sheeted over with thin spar. Calcareous concretions of other kinds also occur, but not in such quantity, or of such beauty, as in the upper middle cave. From this statement, however, I should except the eastern extremity of the largest of them, where several specimens of singular beauty are found, and where, upon the sides of the gallery, the spar exhibits the graceful and brilliant undulations of the richest drawing-room hangings. The dimensions assigned to these galleries must not be received as representing their actual extent: to none of them did we find an absolute termination; and the accompanying chart merely gives the limits at which, in consequence of the difficulties opposed to our progress, further investigation was abandoned.

We shall now, returning to the lower middle cave, examine the outlets of its N. E. extremity. From this quarter of it a branch is sent off to the south, 40 feet in length and 6 in breadth, from the centre point of which there is an offset of about the same dimensions, which takes a N. E. direction, and is crossed at the termination by another gallery parallel to the first, and which has probably, as shall be hereafter shown, a subterranean connexion with that prolongation of the upper middle cave in which the river is found. The cross passage just described, is encrusted on both sides with sparry productions; fewer in number, however, and of inferior beauty to those which occur in the galleries it connects.

The second outlet of the upper end of the lower middle cave, expands, in a N. N. W. direction, into a cavity of an elliptical shape, 90 feet in length, and 45 in breadth, its S.S.E. half being divided into two by a wall of limestone 45 feet in length, and about 15 in breadth. On the western side of this wall, and between it and the side of the cave, occur four or five magnificent pillars, and at the south angle a small cavity, composed entirely of spar, which was described to us under the name of the *bedchamber:* it is entered on the north side, through a narrow hole; and from it, but through a smaller and more difficult passage, it is possible to return into the lower middle cave. The portion of the bedchamber cave to the east side of the stony partition, exhibits nothing remarkable until we reach its N.E. extremity: here, three magnificent stalagmites are encountered, and a pillar of unusual magnitude, extending from the floor to the cieling, and which has received from the guides the name of Lot's wife. This huge stalactitic production occurs at the commencement of an avenue 20 feet long, and about 10 wide, at the termination of which three distinct adits present themselves. One of these faces directly the avenue just described, and leads to the Garrett cave; the other two, which are on the left hand, and distant from each other about seven feet, constitute the respective entrances to the grand Kingston gallery and Sand cave.

The Garrett cave extends 255 feet in an easterly direction, with a sweep to the south; its breadth at the commencement being 15, and augmenting gradually until, at its widest part, it becomes 55 feet. The floor, which is every where covered with blocks of limestone scattered in the greatest disorder, is not horizontal, but ascends by a considerable angle, so as, at its remote extremity, to come within a few feet of the cieling: there is no department of the entire cavern in which pillars, stalactites, and stalagmites of spar are more numerous or more beautiful. The more remote or upper portion, also, of this chamber, is distinguished by the enormous number of small stalactites of from six inches to a foot in length, depending from the cieling, and studding it at almost every point. The cieling also, in one part of the cave, would appear to have recently fallen, the floor being covered with a confused pile of fragmented rocks, and the corresponding portion of the roof being destitute of stalactitic productions.

Upon returning to the entrance of the Garrett cave, and ascending by a steep and rugged passage into the most westerly of the two adits already mentioned, we find ourselves within the grand Kingston gallery—the most remarkable compartment of the entire excavation. It is a perfectly straight hall, 175 feet in length and 7 in breadth, with a direction about one point to the west of north. The arching of this gallery is in the gothic style, and its walls are every where glazed with spar, in some places red, in others mottled, but no where of a perfectly white colour. This gallery, at the distance of 126 feet from its entrance, was originally blocked up by a thin diaphragm or sheet of spar, but it is now perfectly continuous throughout, a passage having been some time ago broken in the partition, through which one individual at a time can pass. Immediately beyond this partition, a large pillar is met with in the centre of the gallery—about 15 feet further on, another of the same magnitude—and some distance beyond this, and in a line, four others of inferior size. The grand gallery terminates in a rectangular cave, 52 feet wide and 30 long, from the north of which there is a passage in the same line with the grand gallery, and which admitted of being explored to the extent of 87 feet.

From the rectangular cave just described, and which is situate about twelve feet lower than the floor of the Kingston gallery, there is a passage leading back to the entrance of the Garrett cave. This passage, which is called the Sand cave, from the quantity of this material which covers its floor, is, for two-thirds of its length 12, and for the remainder 3 feet wide: it is perfectly parallel to, and of the same length with the Kingston gallery, but placed at a somewhat lower level.

On the east side of the rectangular cave in which the Sand cave and gallery terminates, there are two long and narrow entrances, which pass directly E. N. E., the nothern one bending, at the distance of about 13 feet, to the south, so as to meet the other. From this point they constitute a single passage, which proceeds directly south, and then, bending westward, opens into the Sand cave at about 40 feet from its northern point of commencement. This winding channel expands and contracts in its progress, so as to form a string of small cells called closets, amounting, as we were informed, to about twenty in number: these closets, however, though laid down in the map, we did not personally examine. In the Sand cave there are no sparry formations; and, indeed, nothing of any interest which has not been mentioned, save a collection of water in a calcareous basin, within a few feet of its southern termination.

From the preceding brief description, the newly discovered cavern, it will be seen, is not a single excavation, but is composed of a number of chambers, some of greater, some of less magnitude, connected by rugged and narrow passages, the floor of these being generally covered with prismatic blocks of limestone, and the sides and cieling loaded with calcareous incrustations. Pillars also of the same material as has been already described, often connect the floor and cieling; and the masses of limestone on the floor, are, in many places, covered with spar, giving rise to stalagmatic productions of the most varied and fantastic appearance. The length of the entire cavern, from the entrance to the extremity of the long cave, which correspends with the line of section given in the map, is 700 feet; but a line passing through the grand gallery, and extending to the northern and southern limits of the entire series of cavities, would measure 870 feet. Another line, drawn from the entrance to the farthest extremity of the Garrett cave, has an east and west direction measuring 572 feet, which may be considered as giving the greatest breadth of the cavern, or as comprehending its eastern and western boundaries. The floors of the different chambers, included in the annexed section, namely, of the lower middle, upper middle, and long eaves, are very nearly horizontal, and depressed about 55 feet below the grate through which the cavern is entered. The depression of the Kingston gallery below this point is but 47 feet, and that of the eastern end of the Garrett cave but 19. This latter chamber is, therefore, that which comes closest to the surface, and the thickness of the intervening strata is, it may be observed, diminished not only by its actually greater elevation, but also by the circumstance of this portion of the cavern corresponding, not to the apex, but to the north-eastern slope of the hill.

In glancing at the accompanying ground plan, several portions of the cavern are observed to be parallel, all running S. S. E. and N. N. W. Three of these are in a line, namely, the Sand cave to the north, and offsets from the lower and upper middle caves to the south: between these different passages there can be no doubt that there is a subterraneous communication, and that, at certain seasons of the year, they are traversed by running water. It is worthy of remark, that at the time of our visit, water was found at two points on this line, namely, at the junction of the Sand and Garrett caves, and at the prolongation of the upper middle cave, where the river has been already described as occurring. It may be also not uninteresting to mention, that the line of direction just specified, corresponds with that of the dip of the limestone beds which compose the hill.

The manner of formation of sparry productions in limestone caves is so generally known, that it is scarcely necessary to advert to the subject here. Water filters through the roof, containing carbonate of lime held in solution by carbonic acid, and this gas, gradually passing with some water into the atmosphere, the calcareous salt is deposited. The atmosphere within the cavern was, as might have been anticipated, found saturated, or nearly so, with moisture; for though its temperature was not lower than 50°, the pulmonary halitus condensed into a visible cloud, and the body, under slight exertion, became bathed with perspiration; but it did not, it is fair to conclude, contain any unusual per centage of carbonic acid, for it supported, in the ordinary manner, both respiration and combustion. What then becomes of the carbonic acid, the development of which is the immediate cause of the deposition of spar? Why does it not accumulate so as finally to create an irrespirable atmosphere? These are interesting but difficult questions, and the following is put forward only as a conjectural solution of the difficulty. These caves are usually traversed by running water, and as this, at common temperatures, combines with one volume of carbonic acid, the gas may be considered as in a continual process of absorption and removal. It is a peculiarity, also, of aeriform fluids, as Dalton has shown, that however different in density, they will, when placed in contact, blend together so as finally to constitute an equable mixture. Now, as the roofs of limestone caverns are seldom, if ever, so tight at every point as to be altogether impermeable to gases, we perceive in the law which regulates their diffusion, additional means for effecting the elimination of the carbonic acid.

There is a circumstance connected with the structure of stalactitic spars, which must have been frequently noticed, though it would not appear to have attracted much attention, for I do not recollect having seen any allusion to it in books—*all the smaller stalactites are hollow along the axis, but those of a larger size are solid throughout.* This fact, however, it is not difficult to explain. If a drop of a solution of supercarbonate of lime be conceived depending from some prominence in the roof of a cave, the evaporation necessarily takes place from its external surface; and in virtue of this, it will be shortly invested with a film of spar which will, in a great measure, protect its interior from a continuance of the process. The afflux of additional calcareous solution, will augment the thickness of the film first formed, and the greater part of the fluid trickling from above, being carried to the lower extremity of the stalactite already formed, its prolongation downward, in a vertical direction, is easily understood.

To the completion of this theory it would obviously be necessary to explain—1st. Why the stalactite, while small, does not become sealed up at the vertex: and 2dly. Why, when its bulk is augmented, its internal cavity is obliterated.

The reason why the drop with which the formation of a stalactite commences does not become covered with a coating of spar at its lowermost point, appears to me to be, that the hydrostatic pressure of the solution which is constantly flowing down from above, and dropping on the floor of the cave, removes it mechanically as fast as it is produced. The other fact is still more easy of comprehension. The fluid which fills the fistulous cavity of a small stalactite, as well as that which trickles down its external surface, gradually lets fall particles of spar; the deposition, however, in the former case, being much more slow, owing to the obstacle presented by the sparry envelope to evaporation. A real and progressive growth of the internal surface, does nevertheless take place, in virtue of which the diameter of the fistulous opening constantly diminishes, and the cavity itself finally disappears.

Before closing this paper, I should not omit to mention that no bones, either of existing or extinct animals, have as yet been found within the cavern; nor indeed is it likely that any such will be discovered; as, until accidentally perforated through the quarry, it would appear to have been altogether impervious, and therefore inaccessible as a den or place of shelter to those kinds of animals whose osseous remains have been found in such abundance in the cave of Kirkdale, and elsewhere.

A FURTHER ACCOUNT OF THE LIMERICK TRAPP ROCKS.

BY WILLIAM AINSWORTH, ESQ., M. R. G. S. L., &c. &c.

(Read December 11, 1833.)

The attention of the Society has lately been called by an interesting communication from one of its members, to the existence of rocks of an igneous origin in the County of Limerick; and I am happy in being able to add a few notes on their Mineralogical and Geological characters, and on their Geographical distribution.

GEOGRAPHICAL DISTRIBUTION. The portion of the County of Limerick which these rocks occupy is very considerable, and its limits are marked on the map which accompanies this memoir. The two extreme northern points are to the east, the hill of Newcastle on the Nenagh road; and to the west, the hills extending beyond Carrick-o-Gunnell to the banks of the Shannon.

The first or eastern branch occupies the hills about Newcastle, and is cut through by the great road between Limerick and Dublin. It extends in low undulations by Singland-hill to within a short distance of the County Infirmary at the City of Limerick, and is separated by the valley of the Groody rivulet from knolls of little elevation, which protrude from the Cahernarry range towards the former, at a spot called Tuoreen.

The western branch occupies the hill of Carrick-o-Gunnell with its castle remains, and the low range which extends between it and the banks of the Shannon. The continuation of this chain to the south-east is traced with difficulty. At one spot only on the road to Askeaton could I obtain evidences of its existence. On the Rathkeal road stray masses of trapp are first seen at the cottage doors; they then abound in stone walls; and in this vicinity the range may be perceived stretching beyond Mungret Church to Green Hills, where it is formed into distinct summits, a chapel crowning the crest of one. The exact development of the same formations in the neighbourhood of Ballyclough is ascertained with even more difficulty. At Roxborough the trapp can only occasionally be seen cropping through the soil, and the same thing is the case with regard to one or two other hills. The ruin and cemetery of a chapel occur in the valley on a limestone knoll, which immediately neighbours a rugged hill with a base of limestone, but capped by spilites, which become more extensively developed to the north, and then curve round again to the west. Another valley occurs between this hill and a more lofty summit to the south, where the trapp rocks assume a terraced aspect, and continue thence without interruption to Cahernarry. A formation of trapp was also observed to the south of this, near Rathbane on the Roxborough road, which appeared to be related to the knoll with a windmill that occurs near Limerick.

The Cahernarry range is remarkable for its semicircular development, and as first interrupting in a marked manner the uniformity of the plain of Limerick. The clear perception of this peculiar disposition of the trap rocks requires a careful contemplation, from various points, of the physical features of the country, because the line, from reasons I shall afterwards allude to, is oftentimes continued by limestone, and a physical chart of the country would, in many places, differ materially from what is presented to us by the geological relations which are made apparent on a mineralogical map.

The hill of Cahernarry has a small monument on its top, and is generally wooded round its acclivities and partly on its summit. The great road which now winds over this hill is soon to be carried through the valley between it and Knocknea, which long and continuous hill is the western prolongation of the Cahernarry range, towards Ballynaguard, from which, however, it is separated by a valley of limestone.

The Cahernarry range is continued to the south east by hills of the same formation, occasionally interrupted by limestone rocks, which rise with nearly perpendicular walls, the strata dipping in opposite directions above the valley of the Groody.

A quarry opened near Knockaneh, about an English mile from the village of Caherconlish, appears to be at the most northern prolongation of the rocks belonging to this latter range. Not far to the west, and to the right of the cross road, a quarry occurs in columnar porphyry.

The remarkable range of Caherconlish, extending along a fissure which stretches nearly due east and west, may be considered as consisting of four groups. The lowest to the west at Ballynaguard; the next, the group of Mt. Rice, with the mark of the Trigonometrical survey; the group of Knock Rue, to the east of Caherconlish house, and the group above and to the west of the village of that name.

A somewhat lofty hill of bluish white limestone occurs in the foreground of the Rice hills near the village of Inchylawrence, and the same limestone continuing along the foot of this group may be more particularly observed altered into a compact hard rock at the eastern foot of the hill, and again at the western side. A gentle undulation of the ground between this and the village of Ballyneety, is marked by the re-appearance of the trapp rocks which extend across this hill, exhibiting curious phenomena of intercallation in the limestones towards Ballymacrease. The trapp formation of Ballynaguard is prolonged to the south by the hills of Williamstown and Scule, and the last fragment of this formation which I observed in that direction, was amid the limestones of Knockfennel or Grange hills, where the road passes through the rocky strata, to enter upon the picturesque valley of the Holy Cross, and the wild scenery of Loch Gurr.

To the east and south east the trapp formation is soon succeeded by limestone hills dipping at angles, varying from 10° to 15°, to the west, and presenting mural precipices towards the valley of Mulkern river, or that contained between the Sliebh Phelern or Bilboa mountains and Pallas Green hills. This is a remarkable feature in this district, and almost all the precipices which are observed between this and Lynfield in going along the Tipperary road are of limestone and not trapp.

The first and most remarkable of these hills has a Danish fort on its summit, and its precipices fronting the east are covered with a shrubby vegetation, the rock being also traversed by frequent vertical fissures, by one of which I was enabled to enter a water-course for a distance of about 40 yards, and obtain some transparent stalactites.

The groups of Knockgreine above Pallas Green, with its columnar façade at Lynfield, and of Dirk and Knockrue, are of great interest, and present striking features, illustrative of the origin of the trapp formations. The summit of Knockgreine is a depressed or inverted cone, surrounded by rocks, sometimes columnar and of various mineralogical characters, except to the west, where an outlet is afforded to the waters of streams tributary to the Carnogue. The same thing occurs with regard to the Dirk and Knockrue mountains, where numerous springs unite their waters in a more extended valley, to feed a tributary to the same river.

The circular acclivities and dome-shaped summits of the hills of Knockderk and Knockaney, isolated in the midst of the limestone plains, make them look more like single upraised domes and outlying masses, than as proceeding from a force which has acted in lines or circles, and the same might be said of the lofty hill of Knockfearney, were not this supposition in opposition to what is observed in the elevation, communicated to the accompanying quartzite, (indurated sandstones of Mr. Lyell.) Trapp rocks appear to the east of the Pallas Green groups above the Dead river, at the head of Coolnapish marsh, and, on the authority of Mr. Weaver, at Knockouragh near Castletown, probably the most easterly point of these formations. The westerly extent, and the branches to the north-east and north-west I have traced much further than had been accomplished at the time of this geologist's researches; and it is not at all improbable, that ulterior research may lead to the discovery of other portions of these rocks, prolonged apparently so often upon extended lines, and, as in this case, to be traced by the dip and direction of the stratified rocks, or by the accidents of the soil, though the igneous formations themselves appear on the surface, often only at intervals, and occasionally at considerable distances.

The silicious rocks in these districts are conglomerates, reposing on clay-slate, (Mount Seephin, Castle Oliver mountains,) and in mountain ranges, (Long mountain, Flat moory mountain,) with outlying formations of red sandstone, often large grained or brecciated, or small grained and uniform, as at Nodpatrick near Kilfinnan, or Manister Abbey. The sandstone, where it crosses the plains between Bruff and Kilmallock, is yellowish white, or dirty white, with little cement. At the hills of Knockfearny it becomes a true quartz rock (quartzite) compact, massive, uniform, without cement, and white or grayish-white coloured.

The limestones are white and saccharoidal or bluish white at the foot of Knokcfearney, and in the circus contained within the hills of Cahernarry and Caherconlish, and at Loch Gurr. This would appear to correspond with Mr. Lyell's opinion, that saccharoidal limestones are altered formations, though the same thing occurs at Kilmallock, where the limestones are very Fossiliferous, and on the Clare side. The limestones also present great variety of colourings, rose and pink, with various shades of blue and green, of which I have nearly a dozen varieties, obtained chiefly between Adare and Knockfearney. Lastly, these limestones are anthracitous, dark coloured, and non-Fossiliferous, in the vicinity of Limerick city, and at Castle Connel; slaty argillaceous, resisting fire, but containing no magnesia, near Patrickswell and Pallaskenry.

MINEROLOGICAL CHARACTERS AND CLASSIFICATION.

In classing the several Trapp Rocks, I have studied and relied on their external characters, and the effects produced by the action upon them of the blow-pipe and of acids. The classifications I have adopted will be understood from the following Tabular view:—

A. HOMOGENEOUS ROCKS.

1. Petrosiliceous Basalt. Petrosilex. Saussure, &c.
2. Compact Basalt. Basalt. Orthose pyroxenique, Beudant.
3. Earthy Basalt. Trapp. Al. Brogniart.
4. Calcareous Basalt.

Varieties in which the accessary parts are accidental or irregularly disseminated.

1. Compact Basalt with Hedenbergite.
2. Comp. Basalt with Olivine.
3. Comp. Basalt with Titaneous iron and cavities filled with spar.
4. Petrosiliceous Basalt with Augite and Titaneous iron.
5. Earthy Basalt with Augite and Titaneous iron.
6. Calcareous Basalt with cavities filled with Calcareous spar.

B. HETEROGENEOUS ROCKS.

a. With a homogeneous paste, and in which the accessory parts are uniformly disseminated, or in nearly constant proportions.

1. Basanite. Al. Brogniart. Comp. Basalt with crystals of Hedenbergite and irregularly dissem. Titaneous iron.
   - Var. *a.* With dissem. Pyrites.
   - *b.* With oxidulated iron.
2. Amygdaloidal Basalt. (Basanite variolitique Brog.) with calcareoas spar in nodules and mesotype.
3. Titaniferous Basalt. Earthy Basalt with reddish brown crystals of Titaneous iron and with oxidulated iron.
4. Porphyry. (Porphyry, Jameson, &c.) paste of red Petrosilex with red crystals of feldspar.

b. With an heterogeneous paste and the accessory substances either disseminated, grouped, or in veins.

1. Common Spilites. (Brogn.) Paste of various shades of green, with nodules of same and of calc. spar.
   - Var. *a.* With calc. spar in veins.
   - *b.* With culm and oxidulated iron.
2. Chloritous Spilites, reddish paste, with uniformly disseminated Chlorite.
3. Veined Spilites. (Brogn.) Brick red paste, with calc. spar in stripes or veins.

- Var. *a.* With nodules of calc. spar.
  - *b.* With dissem. calc. spar (not veined)
  - *c.* Purple colour, nearly compact, (iron—claystone. Weaver.)
    - Var. *a.* With milk-white feldspar.
  - *d.* Bluish red, with dissem. feldspar. (claystone porphyry. Weaver.)

4. Zootic Spilites (de Bonnard) paste, greenish, with abundant entrochites and occasional nodules of calc. spar and chlorite.

C. With an heterogeneous paste and imbedded parts—rocks resulting from confused crystallization or partial aggregation. Trapp Breccias. Tuffaïtes. Breccias.

1. Greenish paste with nodules of a similar character, and imbedded graphite and flinty slate.
2. Greenish paste with limestone and calc. spar.
3. Lamellar brick red paste with masses of limestone, and entrochites imbedded in limestone.
4. Greenish paste with limestone, and entrochites in paste.
5. Do. with limestone, entrochites, and calc. spar.
6. Brick red paste with ovular green concretions, calc. spar, and entrochites.
7. Angular and rounded fragments of greenish black and black trap, and of limestone with small entrochites.
8. Greenish paste, with dark green or black and brick red fragments, often rounded, and ovular quartz, and disseminated calc. spar.

An example of the first species of apparently homogeneous rocks may be taken from the summit of Mount Rice. In this rock the texture is uniform and homogeneous, the fracture small, grained, uneven, colour greenish black, aspect that of an agglutination of small translucid grains. Before the blow-pipe it fused into a white and black heterogeneous enamel, and did not effervesce with acids. This then might be considered a petrosilex of continental authors; but to avoid the repetition of names, more especially as the mixed character of the enamel and the colour of the mineral sufficiently indicate the admixture of other ingredients, I have included it as a variety of basalt—a petrosiliceous basalt.

The next type, taken from the columnar façades of Linfield and Carrick-o'-Gunnell, had an irregular and fragmentary structure; was homogeneous in its texture; fracture splintery, approaching to conchoidal; aspect glistening; colour greyish black; fusible into an homogeneous black enamel; not acted upon by acids.

This is a compact basalt—an intimate mixture of feldspar and black augite. (Hedenbergite); the composition being only varied in parts by minerals irregularly disseminated and not grouped. These are olivine (Granular Peridot; Hauy, Beudant,) in a granular and lamellar form of translucent, of a greenish colour, sometimes irridescent, and dark coloured augite.

In the third variety—the type of which occurs on the hills above Caherconlish and Pallas-Grein—the structure was fragmentary, texture homogeneous, earthy, almost compact; fracture coarse grained and uneven; aspect dull; did not effervesce with acids. This is a trapp of Alex. Brogniart—an earthy basalt.

The fourth type was characterized by the presence of lime; it was massive and compact in its structure, and homogeneous in texture; fracture even, approaching to conchoidal; colour bluish black; aspect dull; effervesced with acids. This is, therefore, a calcareous basalt.

The varieties which occur in the petro-siliceous basalt are simply due to the admixture of mineral substances irregularly disseminated in the mass. These are titaneum ore (Nigrine,) Knock-Grein, and black auguite and olivine, Ballynaguard, &c.

The varieties in the compact basalts were induced as well by slight alterations in the external characters of the substance itself, as from the admixture of accidental minerals. Among these were some of the basalts of Linfield and Knock-Grein, of a compact massive structure; heavy and iron shot; colour black or reddish black; lustre dull. The disseminated minerals were olivine, titaneous iron, and nodules of spar (Datalite ?); and the basalts of Ballyneety, Ballynaguard, and Carrick-o'-Gunnell, with black augite and olivine.

The varieties of earthy basalts originated in nearly the same admixtures of augite and titaneous iron, only that the constancy and uniformity with which these minerals were disseminated over considerable spaces, more frequently gave to them, as mineral constituents, the character of heterogeneous rocks.

The heterogeneous rocks of the most simple kind are such as have crystals of substances different to the paste so regularly disseminated as to give them a new mineralogical character. Among the first of these is basanite, or basalt, with crystals of augite. I have adopted the name from Brogniart, who very properly revived it from disuse, having been applied to the same substance by Pliny, though given by Kirwan to a variety of lydian stone or flinty slate.

The other heterogeneous rocks are of a most complicated description, and will be best understood from the tabular view itself, which is a sketch of the whole of the trapp rocks which I met with in the Limerick district. With regard to the nomenclature, I can only say, that it is mineralogical, and not geological, and that in adopting the term spilites in preference to that of amygdaloid, pisolite, toadstone, perlite, mandelstein, or blatterstein (Blisierstone), I have been induced to do so because the English names were as irrelevant to the variable nature of the mineral substances which come under this class of rocks as they were to the various forms (amygdaloidal, pisolitic, ovular, spheroidal,) which they present; and of other names, that adopted by those who alone have hitherto attempted a mineralogical classification of mountain rocks—Brogniart (Classif. Min. des Roches, 8vo. Paris); Leonhard, (Agenda Geognostica); and Cordier (MSS. Notes of Lectures)—appears to be the least objectionable. This rectification in the nomenclature of rocks was, however, first effected by Bonnard, (Art. Roche, Dict. Nouv. d'Histoire Naturelle); to which arrangement, Brogniart long hesitated to accede; which, however, he has ultimately done, leaving his former term, *variolite*, to apply itself to rocks with a petrosiliceous paste of various colours, with spheroidal masses of petrosilex of a different colour to that of the paste imbedded.

The varieties of trapp rocks which Mr. Weaver, (Geol. Trans. Vol. 5. Part XIX.) mentions as occurring in this district, were iron claystone (veined spilites), greenstone, basaltic greenstone (basanite), all of them occasionally porphyritic; basalt, both amorphous (earthy basalt), and figurate (compact basalt), amygdaloid (common spilites), feldspar porphyry (Porphyry), and trap conglomerate (Breccia.) There is only greenstone, then, on the list, and the occurrence of which is also noticed by Dr. Apjohn, that was not noticed by myself.

Mr. Weaver further mentions the basalts as containing more or less crystalline hornblende. The feldspar porphyry of the same observer agrees with what I noticed, with the addition of a variety of a greenish grey colour, with a fracture passing from close granular to compact, sometimes approaching to the nature of clinkstone porphyry, and the contained crystals being of a glassy feldspar. Dr. Apjohn has also noticed the existence of glassy white feldspar (Albite ?) in a crystalline dark red *granitic* basis. The occurrence of glassy feldspar in certain feldspathic formations which are not trachytic, is by no means uncommon, and may be remarked among the petrosiliceous rocks of Braid Hills, near Edinburgh, in the ophite of the north western foot of the Pyrenees, or the murchisonite of the Exeter Devonshire trapp rocks. In the present case this compound, says Mr. Weaver, passes into claystone, which sometimes becomes so charged with iron as to pass into iron claystone, both red and black. These rocks I have described under another denomination, and as presenting the same appearances.

GEOLOGICAL POSITION.

Veined Spilites.—The mountain rock which is the most extensively developed in these trapp districts, is the striped or veined spilites, and its geognostic position appears to be threefold. 1st. As an outlying or overlying mass. 2dly. As beds conformably interstratified, and regularly alternating with other strata. And 3dly. As a stratified rock, uplifted or irregularly intersected by dykes of basalt.

The low rounded hills of Newcastle, the range between this and the Cahernarry segment, the northerly portion of this segment, and the hills tangent to it, which extend to the west and north-west towards Carrick-o-Gunnell, are all examples of this rock, which exists there as an outlying mass, often stratified, or resting conformably on the subjacent strata. Its stratification at Newcastle, in the quarries immediately below the castle ruin, at Cahernarry on the hill side, and on many of the adjacent hills to the west, is very distinct; and at the junction of the Newcastle branch with the Cahernarry range, some instructive examples of the interstratification with the limestone rock are offered. Here, following the circular developement which these rocks exhibit, bounding by their abrupt precipices of little elevation, the plains which extend between them and the Bilboa range, and stretching southwards towards the Caherconlish hills, examples are met with of strata of bluish white limestone, having an opposed dip, not only on the two sides of this range, but where the spilites, coming in close contact with them, approach more the central line of the hills; for though the latter rock does not appear to have pierced through the soil, the line of its continuation may be judged of by the open space which exists between the opposed and nearly vertical cliffs of limestone, which are thus separated by picturesque and rocky chasms, while on both sides the strata dip in a different direction.

Dr. Apjohn has also pointed out a nearly similar fact, in contradiction of Mr. Weaver's views on the conformable stratification of these rocks, as exhibited at Castleguard.

These spilites were also, I observed, intersected by dykes of basalt, of which we have examples at Cahernarry, Caherconlish, Linfield, Pallas-Grein, and Carrick-o-Gunnell; and it is probable that if sections were exposed of most of the hills composed of this mountain rock, where they appear as mere outlying masses, we should find them elevated by similar dykes; for in many cases the strata may be perceived dipping in different directions in the same hill.

At Linfield a section of the rock would offer the following arrangement:—

Very slaty and veined Spilites.
Columnar compact Basalt.
Earthy Basalt and Basanites.
Veined Spilites.
Anthracitous slaty beds.
Limestone.

The limestone dips 10° to the south, and the carbonaceous strata and veined spilites rest apparently conformably upon it. Mr. Weaver, who mentions the fact that slaty *iron claystone* is quarried to the westward of Linfield, does not appear to have noticed the spilites lifted up upon the summit of the basaltic facade, and which further support the limestone beds that are met with higher up on the hill. When Captain Sabine, who accompanied me in most of my excursions in the examination of this district, first saw this curious slaty rock, he at once recognised a great similarity between it and representative formations which he had met with in the arctic regions of North America, and the locality of which he gave me as lat. 74° 30′, on the east side of Greenland, and south of the Pendulum Islands. This rock, which I was acquainted with very partially from the writings of European geologists, in the accounts of the Schoalstern of Dillenbourgh, and some of the spilites of the Drac, and which I had not met with in the Auvergne or the Velai, appears to be not uncommon throughout the continent of North America. Thus Captain Bayfield mentions the occurrence of a massive rock of a brick red colour, striped and veined with white, in cliffs on the north side of the easternmost Neepigon Islands (Transactions of the Lit. and Hist. Society of Quebec, vol. i. p. 21.) Dr. Bigsby (Journal of Science, &c. No. 35,) found a similar rock at Thunder Cape, of a red colour, massive and superimposed on alternate strata of red sandstone and limestone, destitute of organic remains. This red rock, Captain Bayfield also mentions as abundant on the western parts of Neepigon Bay. Dr. Bigsby had supposed that it was porphyry divested of its crystals, and also that it passes into sandstone. Captain Bayfield supported the first and least tenable of these positions, but not the second, as he thought that the stripes and veins had given origin to the mistake that the rock was stratified.

As spilites, in all their mineralogical variety, can only be looked upon as altered rocks; their stratification, and their alternation, with sedimentary deposits, or even their passage into the latter, can only be considered as presenting us with circumstances, which, from the nature of their origin, might have been anticipated; and which further illustrate the various sources from whence these formations derive their existence.

In this case the slaty character is so distinctly marked as to admit of no mineralogical hesitation, and has not inaptly, as it is exhibited to the south of Linfield, been compared by Mr. Weaver to piles of boards. Now this character does not belong, or at least very rarely, to the old red sandstone; and even the sandstone of the coal formations, divided as it is into thin seams, does not present so peculiarly a slaty character: while, on the contrary, the micaceous and arenaceous quartzites, or sandstones of the transition series, with their culm deposits, as observed on the banks of the Shannon near Glynn or Kilrush, present us exactly with these features.

I have already ventured to advance somewhat similar opinions on the alternations observable on the coast of Fifeshire, in Scotland, between Bruntisland and Pettycur, of argillaceous and argillo—calcareous and micaceous rocks (unaltered), with spilites and basalts, which contain uplifted limestones and non-bituminous coal. In a case like this, it is impossible not to look upon the formation of a spilite or amygdaloid as the result of a free action given to the particles of lime which thus congregate in little nodules, or fill up the cavities which are offered to them by a change in the conditions of cohesion in the mother rock. And these views, as applied to the trapp rocks of the Limerick district, are instructively exhibited in the elevation of these altered arenaceous rocks and their accompanying carbonaceous formations; but are illustrated with an unwonted force, by the occurrence of fossil organic remains, and of masses of limestone in formations, where calcareous spar is also met with in geodes and nodules, so as to give an amygdaloidal character to a rock already changed in the nature of its paste, and replête with new mineralogical species.

Zootic Spilites. Mr. Weaver had already remarked, that some of the masses of limestone which were imbedded in the trapp breccias of the Limerick districts were so perfect as to contain unaltered organic remains. Mr. de Bonnard has described a trapp formation with a calciferous paste containing portions of entrochite, mingled with calcareous nodules, at Kerzu, near Clausthal, in the Hartz. I found the representative of this rock constituting almost the whole of the hills between Carrick-o-Gunnell Castle and the River Shannon, where it was associated with trapp breccias, containing imbedded masses of limestone; also with organic remains in the limestone, and in fragments in the paste. I also met with the same rock, but in small quantities, in the hills west of Cahernarry.

The circumstances by which the fragments of organic remains are thus preserved in a pyroid paste, must be connected with some preservative power peculiar to these organic structures, and depending upon a difference in their texture from that of the limestones in which they are imbedded, or an actual diversity in composition. Silica, for example, being now known to occur in several zoophytic productions. This peculiarity is, perhaps, best illustrated by a reference to the masses of madreporitic limestone, which may be observed in districts of that formation, and which invariably exhibit themselves most by decomposition—the frequent occurrence of gigantic entrochites in the currents of streams and rivers, as in the bed of the Shannon, the limestone in which they occurred being washed away; and by the appearances presented in limestone caverns, as may be observed in Derbyshire, where the roof and walls of subterranean passages may be observed covered with protruding fossils, which would thus appear to present a greater resistance to the solvent power of carbonic acid, or to the action of running waters—and as bearing on the immediate subject before us, it may be further illustrated by reference to the effects of artificial heat, which renders minute or microscopic crystals. as in the nummilitic limestones of Biarritz, visible to the naked eye, or even renders larger fossils more distinct, giving them at the same time a pearly lustre.

It may likewise be remarked, that from the evidences of these formations, it would appear that a temperature so moderate as to have occasioned a change of condition, without involving the destruction of the masses of limestone; while it would seem to have been most favourable to the preservation of fossil organic remains, and the creation of a zootic spilite, has certainly been least so to the grouping of stilbites, mesotypes, or other minerals of that class, or to the infiltration of agates or chalcedoneys, and thus to the formation of common spilites or amygdaloidal rocks.

Common Spilites. In no part of the trapp district did I observe well characterized specimens of rock with amygdaloidal and ovular cavities, filled with chalcedonic agatine and jasper varieties of quartz, or with minerals of the zeolite family, or druses with prehnite, &c., which are so common in what are generally considered to be the same formations in the north-east of Ireland, in Scotland, and in England. The only varieties of common spilites which were met with in these formations have been mineralogically described. Their distribution was not extensive; their chief locality being the hills above Caherconlish. A variety which was met with in a quarry among the low hills about half a mile north-east of this village, had a basis of dark green petrosilex, with fragments of culm and nodules of chlorite.

CHLORITOUS SPILITES. This rock is not noticed by Brogniart who has done so much towards clearing up the study of these intricate varieties of pyroid formations. The rock, as it is presented to us in the Limerick district, is remarkably distinct and characteristic. Its developement was not very important, occurring only among the rocks above Caherconlish, associated with porphyritic formations and trapp breccias.

TRAPP BRECCIAS. The mineralogical varieties which are presented by the trapp breccias have been already pointed out in the tabular view. In their geognostic position, they may be observed to be every where in proximity to basaltic dykes, though not always in contact with them, and associated with spilites, as intercallated beds, or overlying masses. This is more particularly the case at Carrick-o-Gunnell, Caherconlish, Ballyneety, and Pallas Grein Hills.

BASALTS. It is observable as a leading feature in the basalts, that they are every where found where the trapp rocks rise out of the limestone plains in anything like marked undulations or distinct hills. Knockfearney presents perhaps the only exception to this rule. The trapp rocks on that hill apparently consisting wholly of spilites and breccias. Hills similarly constituted occur in the Caherconlish range, and in the plains west of Cahernarry.

At Cahernarry the basalts are so covered with breccias and spilites, that they would have remained unnoticed but for an excavation made at the foot of the little chapel, and the same thing may be said of Newcastle hill.

The basalts exhibit a columnar form in a small degree at Carrick-o-Gunnell in the precipices beneath the castle and at Mount Rice. The basaltic facade of Linfield is sixty yards wide, and seventy to eighty feet high. The pillars of Kilteely, described by Dr. Apjohn, are chiefly porphyry, like the prismatic pillars I observed near Caherconlish.

The titaniferous basalt which I have described as occurring on the south-western side of Knockgrannea presents a similar tendency towards the columnar form.

*** *Note A.* I am obliged to introduce as a note to this mineralogical account, the occurrence on the south-western side of Knockgrannea, of a copper ore, apparently an oxide of copper (liqueline) in nodules, mostly covered with a thin coating of earthy green carbonate of copper or malachite. This substance had an uneven, splintery, fracture ; of a red colour, and a sparkling semi-metallic lustre. It dissolved in nitric acid at the ordinary temperature of the air, gave a blue precipitate on the addition of ammonia, and a reddish coloured precipitate with the ferrocyanate of potash. The solution produced on the clean blade of a knife a copper coloured deposit in a few moments. This metallic repository had apparently been wrought, but I should suppose without any chance of emolument.

GENERALIZATIONS. The characteristic peculiarities of this trapp formation are the presence of basalts and basanites and of petro-siliceous rocks and porphyries which exist in columnar, figurate and fragmentary forms, associated with and accompanied by trapp breccias containing imbedded masses of limestone and quartz—the occurrence of outlying and intercalated formations of spilites, slaty and veined with carbonaceous deposits, or, fragmentary with calc-spar chlorite, zeolites and culm or graphite—and lastly, a pyroid formation, containing the remains of organic bodies.

The absence of those numerous substances in which feldspar predominates (leucostines trachytes, &c.) might have been anticipated from this peculiarity of grouping. The great masses of trachytic and basaltic formations are generally found very remote from one another. The countries which abound most in basalts (Bohemia and Hesse) according to De Humboldt, have no trachytes, while the Cordilleras of the Andes, which are trachytic for an immense extent, are often entirely destitute of basalts, (Pentland in the Hertha and Edinb. Journ. of Nat. and Geo. Science), and the same thing had been previously observed in Hungary by Beüdant. (Voy. Mineral. au. Hongrie T. 3. p. 500.)

The rare occurrence of olivine is another peculiarity. Olivine, with the exception of the lavas of 1759 at Iorullo, according to De Humboldt, and some of the ancient lavas of Europe, peculiarly characterizes basaltic rocks : but olivine, so common in the basalts of Germany, France and Italy, is rare, as first pointed out by Macculoch and Boúe in the west of Scotland and in the north of Ireland, and now appears to be so in the south. The reputed total absence of the zeolitic family from these rocks, has been established not to be the case, more particularly from the examination of the rocks of Carrick-o-Gunnell, but it is certain that they are extremely rare, and do not at all characterize the spilites, as is the case in most other trapp districts.

The general remarks which I have to make on the grouping together of these rocks, and on the relation which they bear to the crystalline and sedimentary formations are few. The occurrence of trapp associated with quartz rock as at Knockfearney, has already been noticed in Germany; but the trappsandstein of the geologists of that country is stated to surround basalts, and may be of a more recent origin.

Viewing the phenomena generally, it appears that while there is a tendency in the effused trapp rocks to group themselves along a principal line of action, the relation of their distribution, with the great accidents of the soil, is equally well marked. These leading features are evidenced in the circular development which the rocks assume in the first place around the principal fissure of upheaving, or that of Caherconlish, with the upraised groups of Pallas-Grein, and the isolated cones of Knock Rua, Knock Dirk, the Kilteely hills, and their prolongations amid the limestone cliffs of Loch Gurr, and their farther extension in equally well-defined branches to Newcastle to the north east, and to Carrick-o-Gunnell to the north-west—both lines trending in the direction of the curves, formed by the transition rocks of the Bilboa and Keeper mountains on the one side, and the Newcastle and Askeaton hills on the other—and both terminating at the banks of the Shannon.

PHYSICAL FEATURES. The usual trapp or stair-like features which belong to the central line of these formations, is well marked in a sketch which was kindly taken for me by my friend Lt. Weller, R. A. The abrupt escarpments and terrace-like acclivities of the hills, all pretty uniformly front the west north-west. The upraised limestone dips nearly in an opposite direction, or to the south by east, where the limestone is also observed dipping in the same direction, from the north, or beneath the trapp-rocks: which might be supposed to be incongruous with an upraising of the latter in a constant direction. Pyroid formations will be found mostly cropping out still further to the north, though this superadded branch never obtains a similar development on the central group, but is generally in the relation which is offered to us by a section taken near Ballyneety.

The cases in which this dip of the limestone occurred without a corresponding elevation of pyroid rocks, were few. The most striking occur not far to the east of the spot whence the above section was made, where cliffs of limestone rival the trapp hills in height, and appear to dip beneath them without the elevating cause being apparent. The same thing occurs at the limestone cliffs to the west of the Ullva road between Caherconlish and Pallas Grein and the limestone in the plain to the west of the lower hills of Carrick-o-Gunnell presents the same peculiarity. But it must be evident that where the phenomena of interposed injection or interstratification and of subterranean developement are so common, it is not always to be expected that the causes capable of producing this arrangement should be visible or appreciable.

The striking features of escarpments always facing the same point of the compass is observed across the central line of Scotland; where, in the Firth of Forth, the isle of May, Inch Keith, Inch Colm, &c. and the cliffs on the mainland, as Salisbury Craggs, Bruntisland, &c. may be observed to front the west, as they likewise do at Dumbarton and the adjoining cliffs on the Firth of Clyde.

The *plateaux* or table lands formed by these hills have mostly central depressions, but this is no where so remarkable as on the hill of Pallas—Knock Greine—" the sunny hill," so distinguished for its green and rich pasture, a common agricultural character of these formations. Where there are more than one range of these unequally indented ridges or hills with rounded summits, bordered by mural precipices or vertical escarpments, in which the rock is frequently prismatically divided, they may be observed to crop the plains under an oblique angle, and in a nearly parallel position. This, however, does not obtain when the disposition of rocks is in curved lines. In the latter case, or in the circular grouping of the same formations, the disappearance from the surface of the trapp rocks, is oftentimes so sudden and the rock re-occurs again so soon, that what would otherwise be a void, is filled up by raised limestones, which in consequence present their stratified mural precipices to the same point of the horizon as the trapp rocks, and lead sometimes to deceptive geognostic deductions.

The spilites form chiefly round hills of little elevation and without escarpments. These undulations of the ground are so low, that in many places, as in the continuation of the chain of Carrick-o-Gunnell to the south of that of Newcastle towards the city of Limerick, nothing in the physical features of the country would indicate a change in structure.

It is probable that the beautiful scenery of Loch Gurr—its rocky islands, glens and precipices--are to be attributed to the action of subterranean dykes, which I only found cropping out in one place, but which very probably are more extensively developed at greater depths. Nothing else can possibly account for the difference which these rocks present in their external configuration as contrasted with the same formations on the plains.

Tory hill, is also a singular object. It is an almost vertical precipice of limestone, with a lake at its base, rising abruptly out of a champaign country. It would be too venturesome, however, to enter at present upon hypothetical speculations as to the origin of such physical peculiarities in a country so diversified in structure as the plains of Limerick—though such considerations are of the greatest interest, not only to physical geography, but to science at large.

ON THE GEOLOGY OF THE DISTRICT OF FANNET, IN THE COUNTY OF DONEGAL,

BEING THE FIRST OF A SERIES OF PAPERS ON THAT COUNTY,

BY JAMES M'ADAM, MEMBER OF THE GEOLOGICAL SOCIETY OF DUBLIN, AND OF THE NATURAL HISTORY SOCIETY OF BELFAST.

(Read April 9th, 1834.)

The County of Donegal is situated at the north-western extremity of Ireland. If we examine the map, we find its extent to be very considerable, being the largest county in Ulster, and running the entire length of the western side of that province. In so great a portion of the country, a great variety of geographical character may be observed; there is, perhaps, no county in Ireland that displays the same diversified surface.

The coasts of this county are exposed to the fury of the Northern Atlantic Ocean, and we find the effects exemplified in their very extraordinary indentations, presenting in the map a very strange appearance There are several large bays, containing within them a number of smaller ones, affording a variety of appearances, as sand banks, gravel deposits, and the estuaries of petty rivers. In these bays are many islands, and along their coasts many peninsulas of various extents. The circumstance of there being so many bays is much in favor of the geologist. They are of such diversified shapes, and they branch through the country in such an extraordinary manner, that they expose to his observation many phenomena, which would otherwise be less liable to his inspection. They lay bare the edges of strata, and consequently enable their various relations to be determined with greater facility. They also exhibit the action of water on mineral masses, rounding some, and wearing down others. The small rivers which empty themselves into them offer several curious phenomena in the formation of small Deltas, and other tracts of alluvium and transported materials.

Throughout the county there is a vast number of small lakes, occurring at every degree of level. Some of these are found upon the shore, within a short distance of the sea; others occur on the summits of mountains. From the examination of these lakes, much information may be frequently obtained.

The face of the country is so generally mountainous, so little of it presenting a champaign character, that it may be designated wholly a mountainous country. The mountains afford such an infinite variety of shape and arrangement, that we may find examples of every species of elevation.

The geological phenomena of Donegal may be expected to be as varied as its geographical features; and on observation there is to be found a very diversified geological structure. As we are to examine its geology by degrees, we must not at first form any hypothesis of its mineral structure, but leave our conclusions at rest, until we have completed the examination. Suffice it to say, that what are called primary rocks appear to be the most predominant, especially in the northern and central parts—the extreme southern appearing to compose part of the limestone tract, that occupies so much of Ireland. We find over the country many overlying rocks. The alluvial deposits in its numerous bays have been already alluded to, while its coasts afford the most ample means of studying the operations of drifted sand.

If a geological observer leave Dublin on the north west road, he will pass for a considerable way through a secondary limestone country. To this succeeds a district composed principally of grauwackè. In the northern part of the county of Tyrone, he will meet with a primitive limestone, which is the prevailing rock on entering the county of Donegal at Lifford. At Raphoe it may be examined to the best possible advantage. With it is associated mica slate, and there is a frequent passage from the one rock into the other. He may be generally certain that in this county the most fertile districts out of the alluvial tracts are on limestone substrata, and this is exemplified in the district lying between Lifford and Letterkenny, in which the land is uniformly good, with the exception of those parts where the limestone passes into mica slate. This latter rock increases in abundance at Letterkenny, and continues along the high road to Rathmelton, and as he advances farther to the north, the limestone becoming less frequent, and occurring only in very detached localities. The country is here of a wilder and more barren character than that through which he passed, and he enters upon an Irish Highland district of a most interesting and romantic cast.

Mulroy Lough is the central of the three large inlets in the north coast of Donegal. The shape of this lough is very peculiar. Its entrance is very narrow; like a river, it widens as it advances into the country, and forms a number of recesses or coves, one of which is of considerable size, being like a bay within a bay. Perhaps this cove may have been once a lake, the barrier of which had been afterwards burst through, These numerous windings of Mulroy lough afford a number of picturesque views. The sides being uniformly mountainous, afford good terminations to the landscape, and their tints being very varied, they often seem in the distance to be covered with wood. That they have been at one period clothed with trees, is very evident from the number of roots remaining in the ground, and even young trees will at times appear, but are prevented attaining to any maturity from the attacks of the cattle. I was informed by a resident land agent, that were a portion of the hilly ground enclosed, so as to guard it from the inroads of the cattle, a grove of natural wood would arise in a few years. The upper part of the lough contains several islands; there are also several in the inner bay.

If we examine the map, we may observe that *Lough Swilly* runs in a parallel direction to the east of Mulroy Lough. The intervening land forms a kind of peninsula. In the same manner the western side of the latter bay forms another peninsula or promontory, being the division from the third lough, called *Sheep Haven.* This last promontory is known by the name of *Rossgull,* the Irish word *Ross* being the name for a cape. The former peninsula presents a very different shape, being very broad at its northern extremity—it is called *Fannet,* the derivation of which word is evidently from the Irish preposition *favi, under* or down, and means a country at a greater distance, corresponding with the English expression of the metropolis, "going down to the country." It is to the geological phenomena of this peninsula, Fannet, that this paper is more particularly directed.

On leaving Rathmelton we enter a mountain district, in which mica slate prevails, affording the usual phenomena of that rock, the layers often assuming the most grotesque, tortuous appearances. This district appears on the map, as a range running across the peninsula, and it presents a well-defined escarpment on its northern side, but as we approach the north, the character of the rock changes, as shall be presently described.

On leaving this mountain range we enter upon a plain, that, like the mountains, runs across the entire breadth of the peninsula. Throughout this plain, however, are numerous rocky hummocks. On leaving this plain we enter upon another very mountainous district, extending almost to the northern shore, where large masses of drifted sand cover a belt of syenite, that forms the northern border of this peninsula.

Looking again on the map, we may observe the district to the westward of the inner bay. Here, in addition to the primitive formation already mentioned, there is a tract of clay-slate. To this district is given the name of "between the waters of Mulroy."

We find in different parts of Fannet, small formations of primitive limestone, the characters of which shall be described in the sequel of this memoir.

Having given the general features of this district, I shall now enter into particulars. I have stated that it is composed of primitive rocks; but upon these are found some formations of a more recent date. Over the entire district are a great number of overlying masses of trapp, which occur in every situation, and are found upon all the other formations, except, perhaps, the syenite. They may be observed at every degree of level, from the plain to the summit of the highest mountain. They occur in some places as round hummocks, in others as longitudinal ridges—sometimes they are very close to each other, and afterwards suddenly break off, so that several hills composed of other rocks intervene, before they are to be found again. It would seem that the country, after it had received its present appearance of surface of primitive rocks, had been afterwards covered with a deposit of trapp. This would flow into the original inequalities without altering them. By some cause a denudation of this trapp formation took place. Various parts disappeared, leaving the underlying primitive rock uncovered; and in several places forming channels or gullies, the bottoms of which display the original formation, and the sides parts of the overlying mass.

This trapp, or greenstone, occurs on the summit of Murrin, one of the highest mountains in this district. On the west side of this summit it does not occur till within a few feet of the highest point, but on the northern and eastern slopes, it extends to the base of the mountain. A little to the west, another elevated summit occurs, that of Dunmore, between which and the former there is a considerable hollow, at one time evidently filled with greenstone, which has been subsequently swept away, and the primitive rock now remains at the surface. Another hill of less elevation, that of Dunbeg, is in the same line with Dunmore and Murrin, so that these three form a range or escarpment, beyond which the country is called the *Iochdar*, or bottom, and is in every sense of the word a primitive country, the inhabitants retaining many of their original customs. Behind these hills is a valley, running parallel to the range, and which may be denominated a longitudinal valley. Several lateral valleys branch off, one of which is to the west of Dunbeg, and through it runs the high road. A little to the east of Murrin is another valley, called Glenfannet, in which Murrin may be regarded as the northern extremity of its western side, and along this side the greenstone is found partially capping the hills, but in many places the primitive rock occurs bare at the summits. Regarding as the eastern side of this valley the range of hills that rise above Lough Swilly, we find upon this range the greenstone occurring more abundantly, the whole of this side presenting an almost continuous greenstone summit, which is finely developed next the sea coast, the cliffs there presenting mural precipices, as on the coast of the county of Antrim. This is finely exemplified at the cliffs called the *Scuille* rocks.

The regular structure of this greenstone is very apparent. It breaks off in tetrahedral pieces like that of Antrim, and from this circumstance it is very difficult to obtain a fracture. In some parts of the same mass it assumes an appearance as if stratified, as in the summit of Murrin, where the strata appear conformable to those of the underlying primitive rock. But this stratification is only apparent; in the same mass we may observe in one place an appearance of stratification, and a little way off find it perfectly amorphous.

It occasionally occurs in dykes, a good example of which is at Watching Point, on the east side of the peninsula. These dykes are, however, not very common.

The cliffs, called the Scuille rocks, display a fine *trapp* profile, being in the ladder-like form, so apparent in the county Antrim precipices. I obtained much information from the range extending northward from these rocks, and which I have noticed as the eastern side of Glenfannet. The summit of the range presents a platform of greenstone, varying in thickness. At its northern end the greenstone seems in one place to have descended in a narrow stream, leaving the primitive rock exposed on each side. These stream-like appearances of greenstone are by no means uncommon. A good example is in the inner bay to the north of Croaghan. I observed masses of greenstone occurring as overlyers on all kinds of rocks; as on limestone in the district "between the waters." In the same district, on other primitive rocks, it forms the cap of Cashel mountain. To the west of that mountain, it is found on clay-slate, and on the western side of the peninsula it may be observed on mica-slate. In some places farther north it even appears to overlie the syenite; but of this I am not quite certain, as the data for so concluding are insufficient. Many of these greenstone outliers seem as parts of streams proceeding from a larger mass. To the west of Cashel mountain, where it is found on clay-slate, it appears as a narrow stream of considerable length. To the south of this mountain it occurs in frequent hummocks, and in some places is continuous for a short distance, with a seeming stratification. Its stream-like appearance may be observed on the hills beyond Croaghan: where their west flanks are near the road side, it may be seen to good advantage. About Kindrum it rests on limestone.

At the range formed by Murrin, Dunmore, and Dunbeg, its appearance is very fine, and its masses are excellent examples of outliers. It also here affords evidence of its having flowed in streams, as it extends in such forms northward from each of these hills. On the summit of the high cliff, Benabhilmore, situated on the Lough Swilly side, it occurs in patches.

This greenstone is often porphyritic, containing reddish-white feldspar crystals. Sometimes the texture is more homogeneous and compact; sometimes fibrous like hornblende rock; sometimes having a slaty structure, becoming a greenstone slate. I could not distinguish it assuming in any spot a columnar form. One of the ranges of hills, "Between the waters," has a *serrated* outline, like primitive rocks.

Having thus stated the phenomena of these overlying trap rocks, I shall proceed to detail the appearances of the formation to which I have given the general name of primitive rocks. This formation coincides in character with what Dr. Mac Culloch denominates quartz rock, and on which he has published several memoirs; but I am inclined to differ in opinion from that geologist, and to consider many varieties of this rock, as described by him, to belong to the rock called *eurite*. This rock in its most perfect state is manifestly compact feldspar, and by receiving additions of quartz and mica, it presents a great diversity of character. I was very much puzzled on my first examination of this formation in Fannet, and until I conceived it to be a compact feldspar, variously mixed, I was unable to proceed with certainty. In this hypothesis I may be be mistaken, but I shall state the evidence upon which it is founded.

In many masses of this formation, a most perfect and striking rhomboidal structure is presented. These masses are divided into thin laminæ, often only a few inches in thickness; and these laminæ are regularly divided into rhomboidal parallelopipeds, the lines of which are marked upon the superficial planes, as if artificially drawn. In striking these with the hammer, the same rhomboidal shape is manifested in the fragments. Well defined crystals may be observed projecting from the weathered surface of several rocks, appearing as their harder portions, and with every external character of feldspar. There appears to be everywhere, however, a greater or less mixture of particles of quartz, and when this becomes more abundant, the rock is more granular in its texture, but the rhomboidal structure remains unaltered. The particles of quartz vary in size through all grades, from very small, until the mass seems to present a quartz base. These granular particles are often reddish coloured, from the increased oxidation of the iron.

We see that there is a gradation in the mixture of quartzose particles with the original base of the rock. When the mixture of these particles is at the maximum, the rock may then be truly denominated a quartz rock; but when this mixture becomes less, it is evident that a different appellation may be given to it. What, then, is this original base? What is the reason of the rhomboidal structure? The similarity to feldspar was to me so striking, that I am inclined to hazard the conjecture that the rock was originally compact feldspar, but that the addition of quartzose particles has altered the chemical composition, without changing its mineral structure.

Several considerations are forced upon us in viewing this mixture of quartz with feldspar. Is this mixture merely mechanical?—The unaltered form of the mixed substance, being still rhomboidal, would incline us to think so. Is the chemical composition of the original feldspar unchanged, notwithstanding the mass may display a semblance of containing other minerals? Are these other minerals wholly foreign, and are the constituents of the feldspar not drawn upon for materials to compose them?

If the feldspar remain unaltered in its composition, then we see going forward the gradations of the formation of granite, gneiss, and mica slate. If to one of these mixtures of quartz and feldspar there be an addition of mica, a true granite is the result. When these three minerals are in nearly equal proportions, the crystalline form of the feldspar seems to disappear, and the laminated structure of the mass designates it to be gneiss. Proceeding still further in the scale of gradation, the feldspar, yielding in abundance to the quartz and mica, becomes at last so small in quantity, that the rock becomes a true micaceous schist.

I am inclined, therefore, to give the name of *eurite* to this primitive formation in Fannet. It appears to resemble the rock called *hyalomicte* by late French geologists, which is intermediate between eurite and true quartz rock: but under the name of eurite I shall endeavour to describe its different appearances in this district.

Throughout the whole of this formation in Fannet there run quartz veins of various sizes in vast numbers. These often preserve the same thickness for a considerable distance: the colour is generally pure white. Notwithstanding the various mixed states of the rock, the rhomboidal structure is almost universally preserved. In all cases there is much information to be gained from studying the weathered aspect: the schistose appearance is then fully exemplified, the laminæ coming off, parallel to each other, and the surface showing a succession of the edges of these layers. This weathered surface often displays a ligneous aspect, resembling a block of wood. Examples are often afforded of passages from granular to slaty.

This eurite seems to pass into gneiss in the southern part "between the waters," as at the foot of Cashel mountain, although nearer the summit it preserves its original character. To the west of the clay-slate formation, beyond this mountain, it again appears resembling gneiss, although it still retains its rhomboidal structure. At Clogher hill, above Glinsk, its cleavage planes are so perfect, that it is raised as flagstones for floors. Proceeding thence to the sea shore, it passes into well-defined mica-slate. At Doaghmore it appears to end, as syenite and granite there come in, and in this locality it is much ironshot; but from the accumulation of drifted sand, I was unable to trace its relations with the other rocks.

As nearly as I could ascertain, the dip of this eurite is to the south-east. This dip is best exhibited on the Lough Swilly shore, where the rocks present beautiful slopes into the sea—all these slopes being to the south east, and as smooth as if they had been dressed with the chisel. On the eastern faces of the hills these plane surfaces are often visible where the soil is worn away, and they present the same smooth appearance as if produced by art. These exposed surfaces are often of a dazzling whiteness: they are inclined to the horizon in an angle of about 45° ; and a very singular proof of this inclination was afforded to me by the reflexion of the terminal lines of these planes in still water. Sailing on a calm day in the inner bay of Mulroy, to the north of Moaris, I observed the angle made by the incident and reflected lines to be nearly a right angle, the half of which would approximate to the inclination of the planes.

On the western side of the promontory the eurite is much more broken and irregular in its outgoings, which may be explained by the south eastern dip. Here its regular structure often affords a strange phenomenon in the beds of streams running down declivities. In these the planes of the eurite have their edges exposed, and the water leaps from plane to plane, like steps of stairs, forming so many tiny waterfalls. Frequently, from the constant falling of the water on one spot, very deep holes are worn in these steps.

On the eastern or Lough Swilly side, where it forms inclined planes into the sea, these planes are occasionally cut through so as to form escarpments. The highest of these, Benabhilmore, is an admirable example of the mural precipice. Here the planes of the eurite being broken off, as if cleft, present, from their equal hardness, a perfectly smooth face, rising almost perpendicularly to the height of 275 feet. A few small patches of greenstone are on its summit. From Doaghbeg to the Light-house the shore has a very precipitous character, consisting almost solely of successive escarpments, arranged in small semicircular bays, like the northern coast of Antrim. At a small cove, on the western side of which the Light-house is built, the formation suddenly changes—a small rivulet running into it seeming to separate the eurite from the syenite, which latter rock composes the western side of the cove, while the eurite alone occurs on the eastern.

The very diversified shapes of the euritic hills are indeed very striking: we find them often assuming the most grotesque and whimsical aspects, as at Marrigmore, near the Seville rocks—and again about Cashel mountain, the distant view of which is very singular. On the eastern shore small hummocks are frequently worn into arches by the action of the waves—a good instance of this occurs near Benabhilmore.

We may at once conclude that this eurite is the underlying rock of Fannet, with the exception of the space, of no great breadth, between Doaghmore and the Light-house, which appears to be wholly composed of syenite, and perhaps a little granite. But in this euritic formation are beds of limestone and clayslate, which are evidently subordinate beds. There is such a variety, also, in the eurite itself, that it might be subdivided into several species of rocks; but this would be of little consequence, as a constant passage is observed from one to the other. I shall now describe the characters and relations of the primitive limestone.

This limestone is generally of a bluish colour, although it is occasionally found white; but the former is considered to produce the best lime, especially if it be traversed with veins of calcareous spar. In the same quarry it is found of various degrees of purity, a few feet separating portions of very different qualities. It is not customary to burn the limestone which occurs near the surface.

This variation in the quality is very remarkable; but on reference to the characters of the same limestone in other localities, the explanation is easy. I have examined this limestone in different other places in Donegal, and have found it and mica-slate continually passing into each other. Its structure is granular slaty, and it contains mica in various states of admixture: this is sometimes so large in quantity as to present every appearance of mica-slate, and frequently an apparent alternation of mica-slate and limestone in the same mass. I have frequently observed a difference in the degree of effervescence in the laminæ of the same specimen, on being touched with muriatic acid, although each was equally shining. In Fannet I uniformly observed that the more impure the limestone, the more it resembled mica-slate in its external aspect. There I frequently observed large schistose masses, composed of an impure slaty micaceous limestone, presenting every character of mica-slate—the distinct laminæ—their infinitude of wavings—the numerous included veins of pure quartz. We may find in the same mass, within a few feet of each other, portions of pure limestone and of true micaceous schist.

This schistose appearance of the limestone is displayed to great advantage in the shores of the small cove at Rossnakill. Its weathered aspect is precisely the same as that of mica-slate, and the laminæ are very much curved; it contains numerous veins of white quartz. There appears to be a considerable deposit of it here, as it composes, for a considerable distance, the shores on each side of Moaris Ferry, extending northward to Croaghan. Moaris Castle is built of it. The rock on which this castle is built displays the stratification of this limestone to much advantage, its planes dipping about W.S.W., which observation of the dip agreed with the experience of the workmen in the quarries. The stone is also raised by them from the west side, which may at first sight seem singular; but on practice it is found more convenient than working from the opposite or rising side.

In the district between the waters it is found running pretty continuously from the shore of this channel, on which is the ferry, to the southern point. Proceeding up the western side, opposite Rossgall, it is found more sparingly. In these localities it is often overlain by greenstone. At Umricam, limestone, greenstone, and eurite occur near each other: between Doaghmore and Kindrum it occurs more plentifully, especially near the latter place. The inhabitants informed me that a vein of limestone appears to extend from this over to Rossgall. In the most remote part of Fannet, called the Bottom, limestone occurs in different places: where the road from Croaghan ends near the Sand Hills, it is met with of a white colour: farther east, at Toome, it is blue, and has the appearance of mantling round the eurite. On the borders of the syenitic formation it is found more or less impure, as at Ballure, and a few other detached spots. At Springfield, to the east of Croaghan, it displays a rhomboidal structure, like the eurite. From this place to the Lough Swilly shore it occurs very rarely. On this shore I found here and there rocks that effervesced slightly: in a small cave I observed a deposition of calc sinter on the edges of the rocks forming the roof and sides, but I did not see any stalactites.

The formation of syenite extends from Doaghmore, on the western side, to the Light-house on the eastern. It is quite unstratified: it is for the most part composed of reddish feldspar and green hornblende: sometimes it contains quartz. At its junction with the euritic formation, I found some rocks possessing such characters as would indicate a transition from eurite into syenite. Schistose rocks may be seen with reddish feldspar veins, which would seem to compose the gradation from one rock into the other: but these points I was unable to ascertain satisfactorily. The syenite forms the line of northern coast, which is exposed to the fury of the winds, and these have covered it with a series of sandhills and drifted sand, concealing in most places the boundary of the formation.

I observed that the syenite never displays the rhomboidal structure so prevalent in the other primitive rocks: it has a faint columnar form at the point of Rinmore: its surface is often strangely scratched or furrowed. This is seen to great advantage near the Light-house, and at Arabeeran. Occasionally its characters resemble those of granite, as at Doaghmore and Ballure. I observed granite boulders on the headlands near the Light-house.

The only other formation to which I shall allude in the present memoir is the clay-slate, which occurs "between the waters" to the west of Cashel mountain. It occupies there a considerable space, and is occasionally covered with greenstone. Its characters are the same as those of clay-slate in other localities: it is often of a waved aspect, and it contains occasionally decomposed pyrites. It is evidently contemporaneous with the eurite, but I was unable to see its junction with that rock. It is not at present quarried for economic purposes.

I shall not in the present memoir enter upon the description of the rocks composing the southern boundary of Fannet; neither shall I bring forward the result of my examination of the more recent formations, some of which are very curious. I shall discuss these more at length in a subsequent paper, in which I shall adduce similar phenomena from other parts of the county.

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was exhibited at my lectures in that year. No material changes were made in the map from that period till the commencement of the last year, when, in consequence of an engagement made by me, at the meeting of the British Association in Edinburgh, to present my geological map of Ireland at the meeting in Dublin, I carefully examined all my notes, made at different periods, up to that time; and having transferred them to the county maps, I prepared from these accumulated materials the geological map of Ireland, which I had the pleasure to present to the Association in August last. I should observe, that with the exception of a few detached hills of quartz rock in the county of Wicklow, which have been taken from Mr. Weaver's map, the whole of the geological lines marked on the map of Ireland are the result of my own observations, or those of persons acting under my direction, who traced for me the detail of several of the lines of geological boundaries.*

As it is my intention to publish this map, together with a descriptive memoir, as soon as sufficient leisure will permit me to prepare my materials, I shall not at present enter upon the general subject of the geology of Ireland, but shall briefly notice some points which require more consideration and examination than I have hitherto been able to give them; the most important of which are the subdivision of the transition, or graywacke slates, of the conglomerate and old red sandstone and of the mountain limestone.

I had long been aware of the importance of these investigations, but their necessity became manifest in consequence of the valuable information communicated to the Geological Section by Professor Sedgwick and Mr. Murchison, in their admirable description of the succession of rocks which occur in Cumberland, and in North Wales, intervening between the mica slate and chlorite slate, and the old red sandstone, and which have been subdivided by those philosophers into the upper, middle, and lower *Cambrian groups*, and the upper and lower *Silurian system.*

The oldest, or lower Cambrian group, consists of slate rocks, which contain no organic remains. The middle contains a few, but in the upper they are more abundant. The Silurian system of rocks which overlies the Cambrian or transition formation, and is covered by the old red sandstone, consists of alternations of sandstone, shale, and limestone; each subdivision being distinguished from the other by characteristic organic remains. No rocks decidedly belonging to the Silurian system have hitherto been observed by me as occurring in Ireland, and none have been described by others; but as it is probable they may occur interposed between some of our slate formations and the old red sandstone, it becomes a matter of interest to seek for them with care in such localities.

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* The most important of these observations were made by Mr. John Kelly in different parts of Ireland, by Mr. Samuel Nicholson in the northern part of the County of Antrim, and by Mr. Patrick Knight in Mayo.

In respect to the subdivision of the schistose groups, I apprehend no material difficulty in separating the older, which contains no organic remains, from the newer, in which they are more or less abundant; but I do not as yet possess any data to enable me to subdivide those strata which do contain organic remains. This can only be effected by a careful examination and comparison of the fossil organic remains which occur in Ireland, with those of Cumberland and Wales; and I expect we have many labourers in the field who will assist in the accomplishment of this desirable object.

In respect to the mountain limestone series of Ireland, it is probably much thicker than that of England, at least in its proportion of limestone, and possibly it may be found to contain some important members which are wanting in England. The black impure argillaceous limestone (the calp of Kirwan) which occurs in the neighbourhood of Dublin and other localities, and which contains few organic remains, is probably peculiar to this country. In those localities where this rock occurs, it forms the lowest member of the series; in some districts it is succeeded by mountain limestone exhibiting the ordinary character, and organic remains; in others, as in the county of Fermanagh, a succession of sandstone beds, of considerable thickness, is interposed between the lower and the upper limestones; while in the counties of Sligo, Mayo, and Galway, the lower member of the limestone series consists of alternations of limestone and sandstone, above which we find the pure mountain limestone.

The examination of these peculiarities offers an additional field for geological investigation, as also the distinguishing more accurately, than has hitherto been effected, the line of boundary between the old red sandstone and sandstone conglomerates, and the lower beds of the sandstone connected with the lower mountain limestone, as above mentioned.

The foregoing appear to me to be the principal objects for future investigation, connected with the older sedimentary rocks of this country—(I mean, of course, on the great scale.)

In respect to the newer sedimentary and the crystalline rocks, particularly those of undoubted igneous origin, I shall not speak in this place, as I wish to refer more particularly to them when considering some of the papers which have been communicated to our Society during the last year.

I shall only here mention the discovery of a small district of granite at Crossdoney in the county of Cavan, which was made by Captain Portlock, and described in a paper by Lieutenant Stotherd of the Royal Engineers. This small district had escaped my notice, though I must have passed close to its northern edge when tracing the boundary of the graywacke with the sandstone and limestone between Cavan and Killishandra.

We are indebted to the exertions of the officers of the Royal Engineers for much valuable geological information; they enjoy many favourable opportunities of making observations in detail, and what is most important, they possess accurate plans on which to lay them down; and it is truly gratifying to observe that these opportunities are fully appreciated, not only by Colonel Colby and Captain Portlock, but also by the greater number of the surveying officers, and even by some of the sappers.

On the second day of the meeting of the geological section, Archdeacon Verschoyle read a paper on the subject of the interesting trap dykes traced by him near the northwest coast of the county of Mayo; and, as he observed, though their continuity is broken, none being actually visible for any great length in one place, still, from observing the positions and direction of each detached portion, and comparing their composition, which in many are peculiar, he was enabled to trace one dyke for a length of upwards of sixty, and others for forty miles, though their breadth rarely exceeds forty feet. There are eleven of these dykes in Mayo, all of which have an east and west direction.

Towards their western extremities, the dykes traverse the mica slate and micaceous quartz rock district of Erris in Mayo, to the east of which they appear to have been traced through the alternating mountain limestone and sandstone district of Mayo and Sligo, which occupies the northern coast between the Ox mountains and Sligo bay. Archdeacon Verschoyle mentioned his having discovered one of these dykes at Dromahaire, situated to the east of Lough Gill, and consequently to the east of the northern extremity of the Ox mountains, which are composed of mica slate; in which case this dyke, having traversed the mica slate of Mayo, the limestone and sandstone country of Mayo and Sligo, again traverses the mica slate of the Ox mountains, and in continuation appears at Dromahaire in the mountain limestone country to the east of the Ox mountains.

These dykes are certainly very remarkable, and merit a further examination; for if it can be reasonably proved, that a dyke rarely exceeding forty feet in breadth, has been traced for a length of upwards of sixty miles, passing alike through primary and secondary districts, it becomes evident, that the source from which it issued must be seated very deep in the earth, as otherwise we cannot account for a force equal to the projection of a mass of igneous matter through so narrow a channel as forty feet for a length of sixty miles. The want of actual continuity in the dyke on the surface is no proof that the different projections or hummocks which appear do not form a part of one system: such irregularities must be expected, particularly where the dykes are narrow. Archdeacon Verschoyle seemed to think that the continuation of these dykes may be traced to the east coast. As yet there are no data sufficient to bear out his supposition; but I have no doubt, on the completion of the ordnance survey of the country, when we shall be enabled to mark every dyke, and every rock in its true position, that facts will be brought to light, both in respect to the bearing or strike of dykes, and the bearing or strike of the strata, which will lead to important conclusions. All we, at present, know of the strike of dykes is, that in each district they usually effect a nearly parallel direction; but where dykes are observed crossing each other, we must conclude that there have been in that district two distinct epochs of igneous action during which dykes have been projected.

During the progress of the meeting Professor Phillips made two valuable communications on organic remains—one on fossil astacidæ, and the other on the varieties of the belemnite; but as these subjects will be treated at length in Professor Phillips' work now in the press, I shall not enter upon them further than to remark, that Professor Phillips' communication respecting belemnites was followed by some valuable and interesting observatians by Professor Agassiz, in which he stated, that he had observed at the broken end of the belemnite a part resembling the bone of the cuttle-fish; thus pointing out the probability that the belemnite, hitherto considered to belong to an extinct race, may have formed a portion of a variety of the cuttle-fish.

Doctor Jacob also laid before the section some interesting specimens of siliceous fossil polyparia, found in an alluvial deposit near the rock of Dunnamace in the Queen's County. Doctor Jacob supposed that these fossil substances had originally been calcareous, that the carbonate of lime had been removed by some solvent, and the silex substituted previously to the fossil organic remains having been enclosed in the limestone base in which they are at present contained. Examples similar to those described by Doctor Jacob are not unfrequently found in situ in the mountain limestone, particularly near the point of their contact with rocks belonging to a different formation. Thus, at Poolscadden Bay at Howth, close to the junction of the limestone with the schistose strata, we find siliceous corallines enclosed in the limestone. Similar facts may be observed near the contact of our mountain limestone with strata belonging to the coal formation; but where such occur, considerable disturbance appears to have taken place in the structure of the calcareous rock, which is very easily broken into small angular fragments, bearing a strong resemblance to a rock acted on by heat; at the same time, no igneous rocks, or other apparent cause of igneous action, are to be seen. I leave this subject as I find it; but I thought it important to point out the particular localities in our mountain limestone where siliceous fossils are usually found, as future observers may, through minute investigations, be enabled to bring facts to light, which have hitherto escaped the notice of geologists.

I cannot conclude this portion of my subject, without noticing the outline of the geology of the neighbourhood of Dublin, prepared by Professor Scouler of the Royal Dublin Society for the use of the British Association; and I have the pleasure to say, that this clear and accurate work was much valued by all those who had an opportunity of making use of it in the field.

I shall now enter upon the consideration of the several papers that have been communicated to our Society during the last year.

In the month of March Mr. James Bryce read a paper in which the action of trap-dykes on chalk and sandstone is carefully described.

We are also indebted to Mr. James Bryce for a valuable paper on the magnesian limestone, situated near Hollywood in the county of Down, on the south side of Belfast Lough. This limestone has been long known, though not hitherto described; it is peculiarly interesting, as being the only locality in Ireland in which magnesian limestone has been discovered immediately underlying the new red sandstone; and though its area be small, still its geological position is important, and deserves consideration.

Mr. Bryce commences his paper by giving a short but clear description of the composition of the new red sandstone of the vicinity of Belfast. He states, that "it passes in its upper "part into argillaceous and gypseous marls, and occasionally "gives origin to salt springs, rising to a considerable height on the face of the Belfast mountains: it is succeeded by the upper secondary deposits—lias, greensand, and chalk, which are well known as constituting the base on which the basaltic rocks repose. Its middle part consists of sands and variegated sandstones, sometimes slightly calcareous. It occupies the shore of Belfast Bay on the north, as far as its entrance at Whitehead. On the southern side of the Bay it extends over the low grounds between the shore and the Hollywood hills, which compose the north-eastern edge of the great zone of graywacke slate which traverses Down, and the adjacent counties to the west. The strata of this rock range along these hills to the north-east, and intersect the shore of the Bay at Craigavad, about two miles below the village of Hollywood. Owing to the oblique direction of these hills to the line of the shore, the space occupied by the sandstone gradually narrows from Belfast to the east, until it terminates in a point at Craigavad. It is in the lower and narrower part of the area occupied by the sandstone that the magnesian limestone appears."

The magnesian limestone, and the strata which accompany it, rest unconformably on the graywacke, which dips south-east at a high angle, while the secondary rocks dip at an angle of about 30° towards the north, varying, probably owing to local disturbances, a little to the east or west of that point.

According to Mr. Bryce, the succession of strata resting on the graywacke consists, first, of a conglomerate composed of rounded fragments of graywacke and quartz, enveloped in a course cement of sand and clay: it also contains small fragments of yellow carbonate of lime and grey crystaline limestone; and Mr. Bryce observes, "that as the imbedded limestone is probably magnesian, the rock may be called a dolomitic conglomerate." I confess I much regret Mr. Bryce did not ascertain whether these included fragments do or do not contain magnesia, as a portion of his subsequent argument is grounded on the supposition that the rock should be called dolomitic conglomerate.

In continuation Mr. Bryce observes, that on the western side of Cultra quay, a stratum of blue slate clay is interstratified with red sandstone: it effervesces briskly with acids, and may therefore be called a marl slate. To the west of this stratum, beds of limestone are found alternating with the sandstone. These limestone beds vary in thickness from one inch to one foot six inches. Mr. Bryce states, that "by far the greater quantity of this rock is compact and fine-grained, of a grey or bluish grey colour, resembling very closely "those compact varieties of lias used for lithographic purposes. " It is sometimes of a light yellow, or buff colour; and there " are several strata of a grey colour and open crystalline tex" ture, very like carboniferous limestone, or the coarser va" rieties of lias. It has an arenaceous appearance, and is most " probably much mixed with sand. The buff-coloured variety " is that which has been most used for economical purposes. " Mr. Bryce was informed by Doctor M'Donnell of Belfast " that considerable quantities of it were sent, many years ago, " to England by Mr. Kennedy of Cultra to have its magnesia " extracted—that the grey variety has never been employed " for this or any other purpose—and that as Mr. Tennant and " other distinguished chemists visited Mr. Kennedy at Cultra, " and examined the limestone, it is probable that he employed " only that which appeared to contain magnesia. It is there" fore most likely that little of that earth will be found in the " grey variety."

From the above data, Mr. Bryce expresses it, as his opinion, that the magnesian limestone of Hollywood is identical with that of the north-east of England, as described by Professor Sedgwick. There can be no doubt that both rocks occur in similar positions; and however insignificant in point of extent our magnesian limestone district may appear, when compared to that of England—being less than half a mile in length, and about a quarter of a mile in breadth—still I think there are sufficient grounds to support Mr. Bryce's view as to the identity of the magnesian limestone. He further supposes, that the blue calcareous or marl slate above mentioned, and the conglomerate, are equivalents for the marl slate and dolomitic conglomerate described by Professor Sedgwick as occurring in England. This may be the case; but it is to be observed, that a conglomerate, similar in character and composition to that described by Mr. Bryce as resting on the graywacke, and underlying the magnesian limestone of Hollywood, occurs resting on the graywacke, and underlying the mountain limestone at Armagh, and many other localities along the graywacke boundary of the north of Ireland; and I have been informed by Professor Sedgwick and Mr. Murchison, that when, during the last autumn, they first observed some of the more calcareous beds of the conglomerate at Armagh, they supposed it to be the dolomitic conglomerate of the north of England; but, on further examination, they abandoned this idea, and considered it to be subordinate to the mountain limestone. Hence I am led to infer that the conglomerate of Hollywood may correspond with the mountain limestone conglomerate, and not with the dolomitic conglomerate; and perhaps this latter supposition is strengthened by the fact, that a small district of mountain limestone occurs at Castle Espie, on the shore of Strangford Lough, close to Cumber in the county of Down, exactly in a similar position with the magnesian limestone above mentioned. It rests unconformably on the graywacke, and underlies the new red sandstone; it contains in abundance orthoceratites, spiriferæ, and productæ; and no doubt can be entertained as to its belonging to the mountain limestone series, and consequently we need not be surprised to find the mountain limestone conglomerate, which in this case may be considered as an equivalent for the mountain limestone occurring near Hollywood, which is only six miles to the north of Cumber, under the same circumstances as at Cumber. It is to be remarked, that in the great extent of the southern boundary of the graywacke and new red sandstone from Waringstown to Cumber in the county of Down, no mountain limestone or other calcareous matter occurs, except at Castle Espie near Cumber; and on the northern graywacke boundary from Grey Abbey by Newtownards to Hollywood and Cultra, neither mountain limestone nor any other calcareous strata have been discovered, except at the place near Hollywood already mentioned. Mountain limestone occurs to a great extent, underlying the new red sandstone, in the counties of Tyrone and Armagh, and is interposed between the graywacke and the new red sandstone; but, under similar circumstances, it is altogether wanting in the county of Down, excepting in the solitary patch at Cumber.

Mr. Bryce concludes his paper by noticing a number of whin dykes, having nearly a north and south direction, which traverse the sandstone and magnesian limestone beds near Hollywood; and these dykes have had the usual effect of indurating and otherwise altering the several beds in contact with them—the marl slate being changed into flint slate, which does not effervesce with acids, the sandstone being indurated, and the limestone rendered more crystaline.

In June last, the Rev. Sidney Smith read a paper giving an account of some fossils discovered in the mountain limestone of the county of Kildare, accompanied by drawings. Amongst those was a specimen of producta lobata, exhibiting traces of spines arranged in rows; also a remarkable form of spirifer attenuatus, in which the hinge-line is prolonged about an inch each way, joining two processes of a very elegant appearance.

A Specimen of euomphalus pentagonalis is described in this paper, which gives a new and unexpected view of the structure of this fossil. It has been usually considered to be a shell without chambers, and bearing a strong analogy to the *solaria:* but this specimen exhibits well-marked chambers in the inner whorls, but no trace of a siphuncle could be detected. The opinion that the euomphalus is a chambered shell, has since been confirmed by Mr. Phillips, who has discovered similar specimens in the mountain limestone of Yorkshire. Mr. Smith has also described and figured a nautilus and ammonite, which he thinks new.

I am much pleased to find that Mr. Smith has taken up the subject of the fossil organic remains of Ireland; and from the specimen he has given of his powers of observation and discrimination in the minute details which this study requires, more than any other connected with geology, we may look forward with a pleasing anticipation to numerous discoveries which will probably be made by him, when our fossiliferous strata shall have been examined more in detail than they have hitherto been.

In the month of June, Captain Portlock also communicated to the Society an account of a mineral spring which occurs in the parish of Drung and county of Cavan.

The spring is situated close to a stream, and about nine feet above its surface, and it flows directly out of a graywacke stratum.

It is remarkable that the space covered by the water flowing from the well is incrusted by calcareous depositions, and hence it is naturally concluded that the water must pass through calcareous strata, though none have hitherto been discovered in that neighbourhood.

Captain Portlock also mentions a case analogous to this, as occurring in a cavern in the county of Cork, which exhibits abundance of stalactites, though the rock is not calcareous.

These are important notices, and may lead to useful practical results.

We shall next consider another paper communicated by Captain Portlock on the subject of the alluvial deposits examined by him in the flat country to the west and south of the town of Dundalk in the county of Louth. This town is situated at the western extremity of the Bay of Dundalk, an extensive inlet, bounded on the north by the promontary of Carlingford, and on the south by Dunaney point. Captain Portlock observes, that this extensive space is in a great measure occupied by sands, which at low water are laid bare for a considerable distance from the shore, the Dundalk river keeping open a very winding passage. The sand is of a mixed character, and slightly cohesive. He further observes, that to the south of Dundalk, a ridge of graywacke traverses the country, meeting the sea at Blackrock, about two miles to the south of the town. Between this point and the river of Dundalk there is an extensive flat of low and sometimes of marshy ground. Several excavations were made in that space in which marine shells were found beneath a stratum of clay; but even to the south of the ridge, shells were met with, forming a part of the substratum two feet in thickness. The shells found were exactly similar to those now met with on the present sea-beach.

Captain Portlock further observes, that it is quite evident that the sea at one time extended over a considerable part of the now cultivated flat to the south and west of Dundalk; and in endeavouring to explain, or rather to reason on the change, he observes, that it will at once strike the geologist as curious that the present surface does not consist of sand and shells, but of a bed or layer of clay, indicating a great alteration in the character of the deposit, even before the ground had become perfectly dry; and he will see in this, one of those analogies which seem to explain the alterations of fresh and salt water strata in other classes of deposits. In this we have a river to yield mud, and if we can suppose the graywacke ridge of Blackrock to have originally been more entire than it is at present, when the first elevation took place which removed the inner bank from the action of the sea, the deposition within would have partaken of the river or muddy character; but when the ridge which formed the barrier was sufficiently broken down by the action of the sea, the water within would be lowered, and the surface would gradually have become dry and suited to cultivation, as we now find it.

The gradual elevation of land by upheaving from beneath, is comparatively a new subject of interest and observation; and consequently it becomes important that notice should be taken of every well-observed fact of the kind. No doubt, when sought for, the coasts of Ireland will furnish abundant examples of similar elevated beaches, some of which may probably be traced to a period more remote than that described by Captain Portlock.

I have myself observed an important example of the latter kind in the county of Wexford, which I noticed at the late meeting of the British Association.

In this case there is a stratum of rolled gravel, varying in thickness from nine to twelve feet, beneath a stratum of calcareous clay marl, of a drab colour. This gravel bed resembles exactly that now visible on the sea-coast of Wexford, being composed of pepples of quartz, sometimes white, sometimes transparent, mixed with rolled fragments of graywacke and fragments of shells; in some places the shells contained in this gravel bed are so very numerous, that the gravel is raised for manure. The several varieties of shells have not yet been sufficiently examined to enable me to describe them; but it is evident that some of them do not belong to recent species, and it is possible that this deposit may be referable to the age of the Crag of Norfolk described by Mr. Lyell. Many of the marl and shell gravel-pits are elevated upwards of seventy feet above the level of the sea, and the extent of the deposit is very considerable, being at least twenty miles in length by five in breadth. These clay marl and shell gravel beds are evidently of prior origin to the blue clay and white marl beds of the same district in which elks' horns and bones have been discovered. The latter appears to be wholly a fresh water deposit. The surface is composed of moor or peat, under which is a bed of strong tenacious blue clay; below it there is generally a second moory deposit, beneath which is a thick stratum of white shell marl, exactly similar to that found at the bottom of bogs, which is evidently a fresh water deposit. It is in this white marl that the horns and bones of the elk are found; and in all the localities of the county of Wexford in which the remains of the elk have been discovered, the same accompaniments were observed. As yet I do not possess sufficient data to enable me to enter more at length on this subject, but I hope to be able to do so in the course of the present year. The examination of the clay and gravel deposits of Ireland is a subject which opens a wide field for investigation; some have probably been rapidly deposited from water in violent action, as is evidenced by the intermixture of large masses of rock, partly rounded with small gravel, and even clay and sand; in others, a deposition into beds of clay and gravel, alternately coarse and fine, may be seen, showing that, at the period of their deposition, the waters were in a comparatively quiescent state. These observations particularly refer to the *eskers*, or steep-sided gravel ridges, which are so abundant in all parts of Ireland, and which are composed, for the most part, of rolled limestone, varying in size from two feet in diameter to less than half an inch, mixed with clay. In others, particularly in the primary slate districts, as for example the north-west of the county of Tyrone, in the valley of the river Derg, the eskers are composed, for the most part, of an heterogeneous deposit, consisting of large masses of rolled mica slate and quartz, sometimes of mica slate intermixed with small quartz pebbles, sand, clay, and occasionally with the decomposing remains of trees. I have never observed any traces of shells in the eskers, even where, as at Westport, they occur, forming islands in the Atlantic. This is an important character, and one which may serve as a distinguishing mark between the depositions belonging to this class, and those which have been evidently deposited on an ancient strand or seabeach, or those which have resulted from quiescent depositions from fresh water lakes, as is proved by their containing lacustrine shells.

In respect to the relative ages of these different depositions, I am inclined to place the esker gravel deposit as the first in point of age; next to which I would arrange the system of *boulders*, now observed on the surface, and which consist of various rocks. These are probably more ancient than the elevated beaches and other deposits which contain shells. Of this class I would rank that of Wexford as the oldest hitherto noticed in Ireland. This deposition probably extends from Wexford into the county of Wicklow on the north, and Waterford on the south. The next in point of antiquity will probably be the marine depositions of the coast, similar to those described by Major Patrickson as occurring on the east coast of the county of Down, immediately to the north of Carlingford Lough, and those noticed by Captain Portlock at Dundalk, &c.; and, lastly, I would place the white marl, lacustrine, and fluviatile deposits, which contain the remains of the elk, and which are probably still in operation in the bottom of our great lakes and sluggish rivers.

In the foregoing enumeration of recent depositions, I have omitted that which is probably the most ancient of all, namely, the extensive deposit of white and brown potter's clay, alternating with surturbrard or wood coal, and occasionally with silicified wood, which occurs on the southern bank of Lough Neagh, extending in an east and west direction for a length of about fifteen miles, and an average breadth of about three miles. This deposit is very thick in one place in the parish of Clono and county of Tyrone; a boring was made to the depth of 290 feet, without reaching the new red sandstone beds which lie below it. I have never observed any remains of fossil shells in this clay. Similar alternations of potter's clay and wood coal occur in the mountain limestone country to the south of Cahir in the county of Tipperary, and both appear to me to be similar to the well-known deposit of Bovey in Devonshire.

The foregoing arrangement of the clay and gravel deposits of Ireland is thrown out with a view to promote further investigation. It is at all times important to have some system to start with, though it be imperfect, that future observers may be stimulated to seek for facts to elucidate a subject which has not been previously attended to in this country.

At the meeting for May, Doctor Scouler contributed a paper on the quartz rock of Howth. I have not yet seen this paper, consequently I cannot give an abstract of its contents. There are many interesting points to be considered respecting the quartz rock, in connexion with greenstone porphyry, both at Howth and Lambay; and in both places the strata are so well exposed to view on the coast, that their examination is comparatively a matter of little difficulty.

At the meeting for December last, a paper by Captain Portlock was read on the subject of the fossil fish lately discovered in the new red sandstone in the lands of Rhone, parish of Killyman and county of Tyrone. This subject is the more interesting inasmuch as it is the first discovery of fossil fish in the new red sandstone in the British Islands; and further, that these fish belong, according to Professor Agassiz, to an entirely new species, which he has named "Palæoniscus Catopterus."

During the late meeting of the British Association, Captain Portlock submitted a fine specimen of these fossil fish to the inspection of the geological section on the day that Professor Agassiz was to speak on fossil ichthyology; and the latter having been particularly requested by Professor Sedgwick to describe the characteristic difference between the fossil fish of the old and the new red sandstone, he mentioned that it consisted in the particular positions of the dorsal and anal fins; and having drawn representations of each with chalk on the board, it was found that he had accurately represented the character in this respect of the fossil fish exhibited in the Irish specimen, without having previously seen it. As might be expected, this interesting circumstance created considerable surprise, as well as gratification, among the members of the Section.

Captain Portlock accurately describes the position of the new red sandstone, in which the fossil fish occur, in respect to the succession of strata which lies below it in the immediate neighbourhood.

The substratum consists of mountain limestone, many beds of which contain, in abundance, the fossil remains usually met with in that series, particularly spirifer, produtus hemisphericus, and corals, caryophyllea fasciculata, and turbinolea fungites. The limestone in a north-eastern direction from Dungannon is succeeded by strata belonging to the coal series, consisting of the usual alternations of shale, sandstone, and coal, and the new red sandstone rests on the coal series in a conformable position; but in an eastern direction from Dungannon towards Rhone, where the fossil fish occur, the new red sandstone appears to have overlapped the coal series, and to rest directly on the mountain limestone, dipping to the east at a small angle.

Hitherto the fossil fish have only been observed in one small quarry, situated in a valley on the road side leading to Rhone House. They were discovered in the parting between two beds of sandstone, about six feet below the level of the road; but no fish or other fossils were observed in any other part of the quarry, and no more can be raised till the quarry is re-opened.

Captain Portlock observes, "that the little patch in which "they occur, is crowded with these small fish pressing upon "and crossing each other. This is a very remarkable circum"stance, and, considering the small size of the fish, seems to "point to this explanation, that they were fry, sheltering them"selves in some quiet little nook, and were perhaps suddenly "closed in by some unexpected rush of sand, or covered up by a "portion of sand falling in upon them." He further remarks, "that it has been observed, that the fins of fossil fish are al"ways expanded; in consequence, it has been concluded, that "they must have been suddenly enveloped whilst living; such "is also the case with the fossil fish lately discovered in the "county of Tyrone."

In respect to the position in the new red sandstone series, in which the fossil fish occur, Captain Portlock observes, that "the genus palæoniscus, or palæothrissum of Blainville, has, "by continental writers, been appropriated to the schiste bitu"mineux, or marl slate; that is, in the lower portion of the "magnesian section of our new red sandstone, and this position, "or one somewhat higher in our series, appears to correspond "with that in which the Rhone fossil fish occur."

I shall now beg to make a few observations on a subject which I have myself lately brought before the Society, namely, the relative ages of crystalline igneous rocks. It has been long known that granite, sienite, and traps are of different ages; but, upon close examination of the great trap district of the county of Antrim, I have had reason to conclude that, that district has been the theatre of at least eight distinct epochs of igneous action on the great scale, without going into the detail of the successive streams of igneous matter which belong to, and are included in, each principal era of the tabular trap, or of the relative ages of the numerous trap dykes. These observations led me to the consideration of the relative ages of *all the igneous rocks* of the county of Antrim, as indicated by their relations to each other, and also to the sedimentary rocks with which they are associated, and the following has been the result in an ascending order:

1. Granite.
2. Sienite, which occurs in veins traversing mica slate.
3. Lower tabular trap of the county of Antrim.

4. Sandy Brea porphyry.
5. Upper tabular trap of the county of Antrim.
6. Cushendall porphyry.
7. Intruded mountain masses and hummocks of crystalline trap, which have been forced through the upper and lower tabular traps.
8. Trap dykes.

The granite of the Antrim district is described as presenting the usual cleavage lines, both lengthways and across, which divide the rock into cubical or rhomboidal masses; but it exhibits no tendency to stratification. It is composed of brownish red feldspar, quartz, nearly transparent, dark brown mica, perfectly crystallized in six-sided prisms, and occasional specks of dark green hornblende. In some localities the rock contains large crystals of brownish red glassy feldspar, in which case it assumes the character of porphyry.

The peculiarities of this rock are perhaps best developed at Castle Park, situated on the coast immediately to the north of Cushendun Bay. In this place the granite rises up from beneath the mica slate in the form of a low hummock; its general structure is porphyritic and occasionally the crystals of brownish red feldspar are large and beautiful.

To the northward of the hummock, the granite passes *rather abruptly* into an unstratified rock, having the internal structure of gneiss, the plates of mica being arranged in laminæ. On the great scale this rock presents a rough outline, and appears in masses rising up in elongated pyramidal forms, having three sides meeting in a sharp edge on the top; it is evidently mica slate which has been partly fused by its contact with the granite; and if we trace this rock to the northward and southward from the granite, we find that it graduates regularly into stratified mica slate.

The mica slate is succeeded by strata of the old red sandstone, and this latter rock by the new red sandstone.

In respect to the age of the granite of Antrim, as compared with the sedementary rocks of that district, I have given it as my opinion, that it is newer than the old red sandstone, and older than the new red sandstone.

The latter rock at the arch near Red-bay Castle presents a conglomerate character. The mass or base is composed of disintegrated mica slate, which contains fragments of mica slate, granite, porphyritic granite, quartz, and old red sandstone. The character and composition of these included fragments are so strikingly similar to the corresponding rocks of granite, &c. situated immediately to the north, that no doubt remains as to their identity; it becomes consequently evident, that the granite is older than the new red sandstone. It is certainly more recent than the mica slate with which it is in contact, as is proved by its containing fragments of that rock; and as the old red sandstone contains fragments of mica slate and quartz, but none of granite or granitic porphyry, there are reasonable grounds to conclude that the granite is also newer than the old red sandstone.*

With respect to the sienite of the county of Antrim, which, as well as granite, occurs associated with mica slate, it is evidently newer than the granite, inasmuch as it is found intruding in the form of veins into the chalk which rests upon the new red sandstone. The sienite is composed of dark green hornblende, frequently crystallized in the form of six-sided prisms and brownish red feldspar; it is altogether a fine-grained rock, and frequently includes angular masses of mica slate.

Hitherto the sienite has only been observed at Goodland Cliff, immediately to the south of Murlough Bay, in the form of veins which traverse the mica slate nearly in the direction or strike of the strata. There are two principal veins at this place, which may be traced along the face of the mica slate cliff for a length of upwards of half a mile. On reaching the top of the precipice, one of these veins, or a rock which is identical with it, is found penetrating chalk on the summit of Torr Eskert hill. At the point of contact the chalk is highly indurated, and the sienite frequently includes small fragments of the chalk; but it is remarkable that detached reniform masses of sienite are also found included in the chalk, which leads to the conclusion, that the sienite vein was projected into the chalk at a period when that rock was in a soft or plastic state. The discovery of sienite traversing chalk is a new and important geological fact upon which I need not dwell, having already described the facts at length in a paper communicated to the Geological Society of London; but if my views be correct, it would appear that two of the rocks formerly classed among the oldest of the primitive formations, must now be considered coeval in point of date with some of the most recent of the secondary.

The great tabular trap series of the counties of Antrim and Derry comes next in order; it had been divided into three epochs, but the intervals between each were probably not of great duration. The lower trap series is separated from the upper by a sedimentary deposit, consisting, for the greater part, of red ochre and lilac-coloured lithomarga beds speckled with white; in some places the lithomarga beds contain crystals and rounded pebbles of quartz, and occasionally the mass passes into a sandstone. These sedimentary deposits are also frequently accompanied by a bed of wood coal; where it occurs, it is usually covered by a bed of trap, but the substratum consists of sandy, clayey, or ochreous matter.

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* The granite of the County of Antrim is probably more recent than that of Wicklow, or of Down, Galway, or Donegal.

The ochre, lithomarga, sandstone, and clay beds, and wood coal, have been observed in numerous places both in the exterior and interior of the trap district, but they are best exposed to view on the Causeway coast. At Brown's Bay in Island Magee near Larne, the lithomarga beds are two hundred feet thick, in others they vary from ten to fifty feet.

The ochre beds probably originated in the projection of volcanic ashes from a submarine volcano, and the clay beds, sandstone, and wood coal, were deposited among them at the bottom of the sea during the interval of the great eruptions of perfectly fused lava. It will be observed that the tratitic porphyry of Sandy Brea is placed in the series of epochs between the lower and upper tabular traps; and, in fact, in the position of the ochre and lithomarga beds, this position has been assigned to it in consequence of passages from the tratitic porphyry into the ochre and lithomarga beds having been observed at Sandy Brea, particularly under the trap which forms the cap of Carnairney-hill, and interposed between it and the columnar trap situated at the base of the hill to the south, which underlies the porphyry. A passage from the ochre beds into porphyry may also be observed in the alternation of red ochre and lithomarga beds visible at the cliff above the deep pool called the Bull's Eye, which forms the bank of the river, a little beyond the western extremity of Glenarm Park. Commencing from below, the trap which forms the bed of the river is covered by ochreous strata, resembling indurated clay of a lilac colour speckled with white, exactly similar to that of Brown's Bay and Bengore Head. This stratum is succeeded by a series of thin beds of ochreous clay, which vary in colour from yellowish brown and brownish red to light red. The top of the cliff is composed of a stratum of tabular greenstone. These ochreous strata occasionally contain small crystals of quartz in double six-sided pyramids, and bear a strong resemblance to the decomposed clay porphyry of Sandy Brea.

Some of the sandy lithomarga beds below the upper bed of wood coal situated to the west of point Pleaskin on the Causeway coast show signs of a passage into porphyry; the quartz pebbles in many cases have been evidently fused, and have assumed the external aspect of semi-opal. From these and other facts, for the detail of which

I must refer to the above mentioned paper, I am of opinion, that the Sandy Brea porphyry is identical with the ochre and lithomarga beds of the Causeway coast, which, subsequently to their deposition, have been fused or partially fused.

The peculiar porphyry of Cushendall is placed as sixth in the order of the igneous epochs of the county of Antrim, but there are no certain data to determine whether or not, it is of prior origin to the great mountain masses of trap, which have been forced through the lower and upper tabular trap series. The Cushendall porphyry exhibits very different characters in different parts. In some places it presents a dark blackish grey base, containing a few scattered crystals of quartz and glossy feldspar; in others, it has a brown or reddish brown siliceous base, with imperfect crystals of yellowish white feldspar, and dull-looking crystals of brown mica. On the shore at Cushendall bay, near the point where the porphyry is covered by the red sandstone, it assumes a minute columnar structure, the mass being divisible into small prismatic fragments, presenting imperfect hexagonal and pentagonal figures; the columns vary from four to ten inches in length, and from one to three inches in diameter. In this columnar porphyry the base is of a light-reddish grey colour, and the crystals of feldspar are more perfect than in other places.

The Cushendall porphyry extends from Cushendall Bay, in a western direction, for a distance of about one mile, and terminates at the north-eastern base of Lurgethon mountain; it forms a number of low but steep rocky hills; it is succeeded on the north by the old red sandstone, and on the south by the new red sandstone. The old red sandstone strata, near the point of contact with the porphyry in the valley of the river above Cushendall, have evidently been forced by the upheaving action of the intruded porphyry, into a nearly vertical position. The dip of the sandstone approaching the porphyry is south-east, at an angle of about 45°; close to the junction the dip is to the north, at angle of from 70° to 80°. This change in the direction and angle of the dip does not generally extend for a distance of more than one hundred yards from the porphyry, and the angle of inclination is observed to lessen in proportion as the distance from the porphyry increases.

The strata of new red sandstone which occur in contact with the porphyry on the south side, have also been upheaved in a similar manner, though the angle of inclination does not exceed 35°.; but it is to be observed, that the base of the new red sandstone conglomerate is much harder and more compact *near the contact* than in any other part.

From these data it is inferred, that the Cushendall porphyry is of subsequent origin to the new red sandstone; whether it is also newer than the tabular trap which covers Lurgethon mountain, and which rests nearly in a horizontal position on top of the chalk, and the new red sandstone, cannot be determined with any certainty; but taking the general position of the respective rocks into consideration, it appears probable, that the Cushendall porphyry is more recent than the chalk and tabular trap.

Many geologists have considered the Cushendall porphyry to be nothing more than the old red sandstone fused by subterranean heat; there are certainly some grounds for this supposition in the porphyritic character visible in several of the stratified sandstone beds, and also from the porous and semi-fused character which the rock usually presents; but whether this be the case or not, it is evident that the great mass of the porphyry now visible at the surface, has been completely fused and forced up through the old red sandstone strata.

In the seventh epoch are placed the numerous round and frequently cone-shaped masses of trap, which are evidently posterior to the lower and upper tabular traps, and which have been projected through them. This fact is clearly exhibited at Kenbane Head, where the course of the trap eruption may be traced from the sea, passing upwards in great masses through the chalk and tabular trap; and the chalk in contact with the erupted trap has been so much acted on, that when struck with the hammer, it falls into white sparkling sand, and the cohesion of the rock is so much destroyed, that a sound specimen cannot be procured. Indurated masses of chalk are also frequently to be observed included in the trap.

The coast between Kenbane Head and Ballintoy presents numerous examples of trap islands belonging to this period. These islands are quite distinct in external character from the tabular trap; the divisions or lines of cleavage, instead of being horizontal, approach to a vertical position; these lines frequently present a sinuous structure, and may be observed twisted into curved and fantastic forms. When these intruded masses are of considerable size, the rock usually exhibits a highly crystalline structure. This is particularly the case at the Skerry Islands, at Ramore Head, Port Rush, at Fair Head, and Ballygalley Head, &c., and more in the interior of the country, Ballygawn, situated two miles north-west of Ballygalley Head, Sleamish mountain, Tievera near Cushendall, and many others.

All these mountains present quite a distinct external aspect from the surrounding trap, being rounded or cone-shaped, and considerably elevated above the adjacent country; the interior structure is much more crystalline, and in many places approaches in character to the crystalline greenstone usually met with in primary slate districts.

Owing to the covering of peat, and sometimes of alluvial matter, the direction of the jet of the eruption is rarely visible in the interior mountains; but the upright cleavage and unusual crystalline structure is sufficient to prove a distinct origin from the comparatively earthy and amygdaloidal trap arranged in horizontal beds, which characterize the lower and the upper series of the tabular trap of the county of Antrim.

Perhaps the decidedly eruptive character of these great intruded mountain masses may be best observed at the mountain of Ballygawn already mentioned, which is situated two miles to the north-west of Ballygalley Head, between Larne and Glenarm. At this place the upright course of the trap, about sixty yards in breadth, can be clearly traced passing through the chalk, which on either side has been forced from a horizontal to a highly inclined position, and may now be seen resting on the steep and smooth sides of the erupted trap. At the contact on the south side, the chalk, when broken, presents the character of a bluish-grey trap, and when examined, it is found to be composed of rhomboidal crystals of carbonate of lime, intimately mixed with crystals of hornblende. A few feet from the contact the hornblende is wanting, but the chalk assumes the structure of a large-grained crystalline marble, of a bluish-white colour. At the distance of about thirty feet, the chalk has an arenaceous structure, and is actually quarried for the purpose of being beaten into white sand for domestic purposes. Beyond the quarry, the action of the trap on the chalk may still be observed for a distance of about thirty feet, so that the crystallization or induration of the chalk may be traced altogether for a distance of about sixty feet from the outer surface of the trap.

On the north side of Ballygawn, the chalk in contact with the trap has been acted on in a similar manner, excepting that no crystals of hornblende occur.

It may perhaps be well to remark in this place, that no example of the tabular trap having indurated the chalk in contact with it, has hitherto been observed in the county of Antrim; and consequently the crystalline structure of the chalk, in contact with the projected trap, may be considered as one of the characters by which the tabular and projected traps may be distinguished.

The hill called Tievera, situated half a mile to the north of Cushendall, affords another striking example of projected trap.

This hill presents the remarkable appearance of a truncated cone, rather rounded off on the top, rising from another mountain whose acclivities are not nearly so steep.

The summit of Tievera is composed of highly crystalline greenstone, in which the crystals of hornblende and feldspar are so much interlaced as to create an open porous structure. This circumstance has caused much external disintegration; but, in the interior, the rock presents a beautiful crystalline fracture. At the base of the steep cone, or about two hundred feet below the summit, the greenstone is covered by highly-indurated beds belonging to the old red sandstone; in some places near the contact, bluish-black flint-slate is intermixed with a dark bluish-grey fragmentary rock, containing some minute white specks; it is so compact and close-grained, as to bear a strong resemblance to some varieties of greenstone porphyry; but, on careful examination, large rolled masses of quartz, similar to those which occur in the old red sandstone of Cushendall river, are observed included in the rock; and on tracing the strata downwards from the contact, this rock graduates at no great distance into the old red sandstone, so that no doubt remains as to the altered rock being a portion of the old red sandstone. This altered sandstone and flint-slate may be observed near the contact with the greenstone on the different sides of Tievera, and in every case the inclination of the strata is nearly parallel to the declivity of the mountain; beneath the cone, the angle varies from 20° to 25°, the steepest being next to the greenstone. On descending the hill for about 200 feet beneath the contact with the greenstone, the old red sandstone strata are fully exposed to view in quarries on the side of the old road from Cushendall to Ballycastle. In these quarries the dip is south-east, at an angle of 15° from the horizon.

It may be well, in this place, to consider, whether or not these great intruded masses, which in many cases, as at Sleamish, assume the magnitude of considerable mountains, have not been the agents which effected the present conformation of the surface of at least the primary district of the county of Antrim.

At one period the chalk must have occupied a horizontal position at the bottom of the sea, and the tabular trap which flowed over it in successive streams, must also have occupied a position nearly level; but when, as at present, we frequently find both these rocks perched at considerable heights above their ordinary level, forming detached caps on the summits of lofty mountains, it becomes evident that the chalk and tabular trap have been lifted up to their present positions by the elevation of the mountains on which they rest.

If my views as to the relative ages of the igneous rocks of the county of Antrim be correct, it would appear to be probable that the period of the protrusions of the mountains of Sleamish, &c. &c. was also the period of the elevation of the mountains of Knocklayd, Croghan, Slieveaura, Ballypatrick, &c. &c. all of which are composed of mica slate, capped by chalk and trap; but that in these cases the projective force of the fluid trap, though unable to force its way through the mica slate, still possessed sufficient power to elevate it into mountains.

The summit of the trap on Knocklayd mountain is elevated 1685* feet above the level of the sea, while the ordinary level of that rock in the surrounding district, when undisturbed, rarely exceeds 300 or 400 feet above the sea.

I need not at present enter upon the consideration of whin-dykes, which are placed in the seventh or last epoch of igneous action in Antrim. These peculiar veins have evidently been projected at different periods, as is proved by their crossing each other; but, as has been already observed, in each particular district the whin-dykes of the same age effect a direction nearly parallel to each other. In the county of Antrim, the greater number have a direction nearly north and south; and those which traverse the county from north-west to south east, are probably the most recent.

It is a remarkable fact, that as yet, I believe, no whin-dykes have been discovered traversing either the granite or the mica slate of the county of Antrim; they occur in abundance passing through the trap, chalk, lias, and new red sandstone, the coal formation, and the old red sandstone; but, like the trap of the previous period, their projective energy appears to have been unequal to force a passage through the granite or mica slate.

The relative ages of the igneous rocks of the county of Antrim, as far as I know, have not hitherto been brought forward in a distinct form; and what I have done may be considered merely a commencement of such a classification, not only in that county, but throughout Ireland.

In the county of Donegal we shall probably find five or six epochs of igneous action, some of which are probably prior, and others of coeval origin with those of the county of Antrim.

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* Ordnance Survey.

At the last meeting of the Society, Doctor Scouler contributed an interesting paper on the trap of the county of Limerick. This district had previously been described by Mr. Weaver, in the Transactions of the Geological Society of London, and in our own Transactions, by Doctor Apjohn and Mr. Ainsworth, notwithstanding which, Doctor Scouler has been enabled to contribute several new facts, and I doubt not, many yet remain to be observed.

Doctor Scouler describes the trap of Limerick to consist of a number of elevated and unconnected masses scattered over the carboniferous limestone country. These masses are very numerous, and occur in an area of twenty miles in length by eight in breadth; about twenty have been discovered, but probably several small ones still remain, which have not hitherto been noticed.

According to Doctor Scouler, the most important of the trap hills already known, are those at Carrig-Ogunnel, Newtown Hill, Cahirnarry, Herbertstown, Knockferna, Pallas Green, Kilteely, Cahirconlish, and Mount Rice; in addition to which may be added Knock Rua, south of Pallas Green, and Grange Hill, south of Six-mile Bridge, and Newcastle, east of Limerick.

Doctor Scouler is of opinion, that the whole of the trap hills have been projected through the mountain limestone, and as might be expected at the contact, the limestone strata have been much disturbed, and the internal structure rendered crystalline; the organic remains have disappeared, and in many places masses of the limestone are found included in the trap.

In the immediate vicinity of the picturesque trap rock, on which the old castle of Carrig-Ogunnel stands, there is a series of low hillocks, composed of breccia, consisting of fragments of trap and limestone, with abundance of organic remains; the fragments are connected by a paste, composed apparently of an intimate mixture of trap and limestone, in which the eye cannot easily distinguish the components. The weathered surface of this remarkable rock presents a beautiful green colour, resembling some varieties of serpentine. Where this breccia approaches the centre of the hill, it passes into an extremely compact rock, in which the outline of the fragments of trap and limestone is lost, and their respective situations are only indicated by blotches of different colours.

In these low hillocks, the solid trap no were appears at the surface; but the more elevated rock on which the castle stands, has evidently been protruded through the strata. This solid trap is composed of an extremely fine aggregation of black augite and feldspar, perfectly free from extraneous matter.

At Cahirnarry, Dr. Scouler observed a very remarkable variety of trap, which, on exposure to the air, presented a number of irregular spheroids, varying in size from one to two feet in diameter; they are evidently the result of a globular structure, rendered visible by the disintegration of the surface. This breccia is composed of fragments of trap of the size of a pea, enclosed in a paste of earthy trap or wacke.

The trap of the county of Limerick is not found in contact with any rock but limestone, except at Knockferna, south of Adare, where it is bounded by sandstone for three sides of the hill, and by limestone on the fourth. In this case the trap has been protruded near the contact of the limestone, and underlying sandstone, and both rocks have been acted on by the contact of the trap—the sandstone having been rendered much harder and more compact than usual, and the limestone more crystalline.

There are several other interesting particulars contained in Doctor Scouler's communication, on which I need not dwell, as the paper itself will be soon before the public. I shall only observe, in conclusion, that the trap district of Limerick is exactly similar in position, and probably belongs to the same era, as the trap hills of Allen, in the county of Kildare, and of Croghan, in the King's County, which are both decided examples of igneous eruptions through the carboniferous limestone and the old red sandstone conglomerate.

In point of relative age, I should think that the trap of Limerick, of the King's County, and Kildare, is coeval with the last eruption of igneous rocks in the county of Antrim.

I have thus taken a rapid sketch of the Geological Transactions of Ireland during the past year, including the communications made to the Geological Section of the British Association, as well as to our Society; and I feel we have much reason for congratulation on the progress that has been made, and the character we have established, among the *élite* of the scientific body of Europe, lately assembled in this city.

I shall now conclude my labours; but in resigning this chair, I must beg to express the high sense I entertain of the honour conferred upon me, in having been selected to fill it. I regret that public avocations should have prevented my being present at many interesting meetings of the Society, and also from contributing as much to our Transactions as might have been expected. I trust, however, that my valued friend Colonel Colby, whom you have this day chosen to succeed me, will be enabled to attend more regularly than I have done, and that he will continue to display that ardent zeal in geological researches which has hitherto marked his career in the scientific world, as well as in the performance of his arduous public duties.

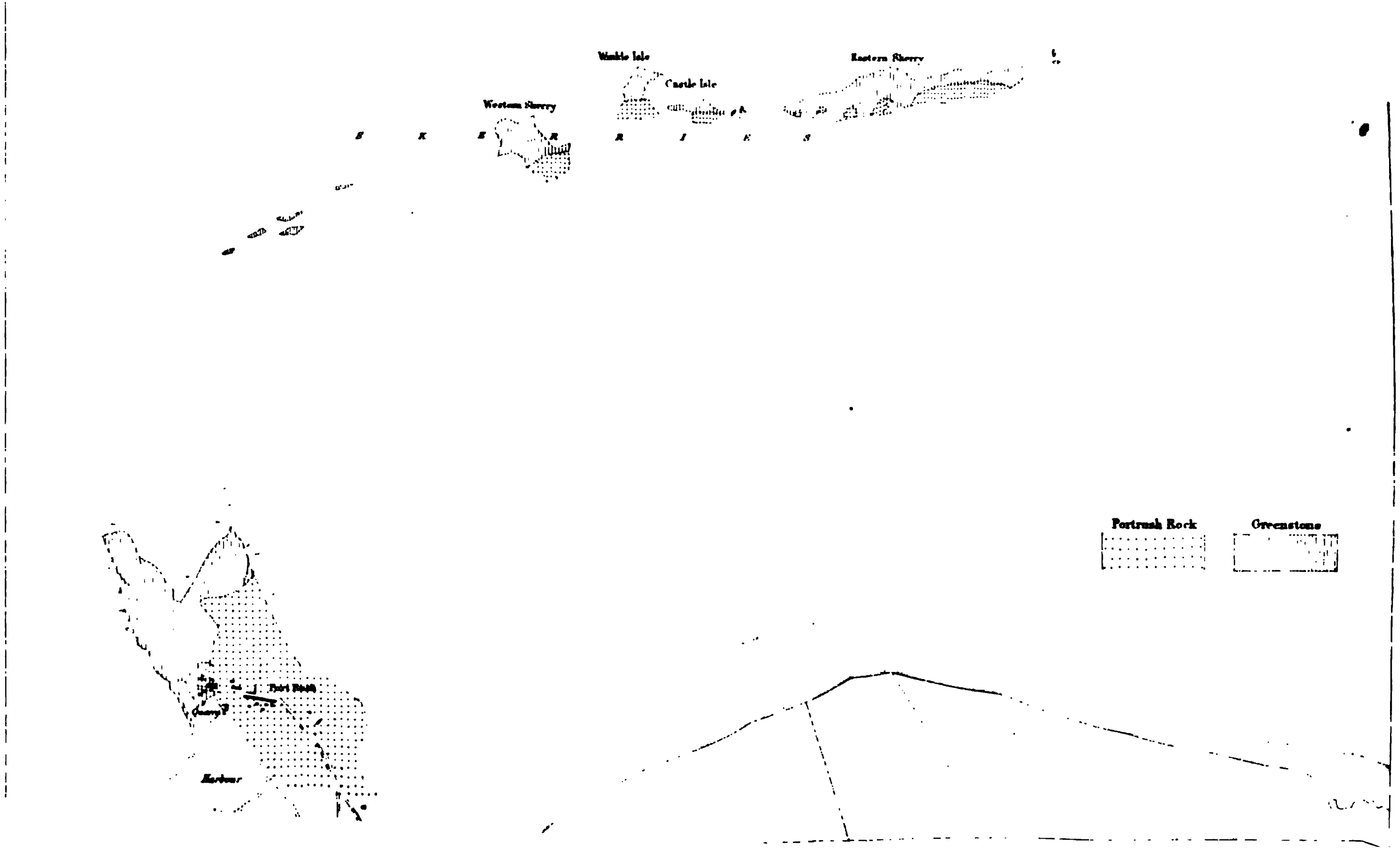
AN ACCOUNT OF THE CELEBRATED PORTRUSH ROCK.

BY JAMES BRYCE, JUN., M.A.F.G.S. CORR. MEM. R.G.S.C. &C.

(Read, December 10th, 1834.)

1. A rock occurs on the sea-shore near Portrush resembling basalt very closely, but containing fossil shells. Its nature has been much controverted by the supporters of the rival theories of Hutton and Werner. The Wernerians maintained that it was a regular basalt, and adduced its marine testaceous remains as a proof of the aqueous deposition of the trap rocks. The Huttonians replied, that it was not basalt, but a flinty slate, probably a member of the lias or coal formation, which had acquired a high degree of induration by the contact of an ignited mass of whinstone. We have thus on record the opinions of many eminent Geologists respecting this rock, given in the way of casual notices; as no connected account of it has appeared, and as I have lately observed some facts, which seem to be inconsistent with all that has yet been written about it, I am induced to hope that the following remarks will not be unacceptible to the Society. They are accompanied by a coloured map, a section, and specimens.

2. The peninsula of Portrush is the extreme north-western corner of the county of Antrim. It runs out three-quarters of a mile from the general line of coast, and is a quarter of a mile in breadth. On the western and north-western sides it is fenced with perpendicular cliffs of 70 to 80 feet in height. From this side, the surface slopes to the east and dips gently into the sea, the shore presenting no elevation deserving the name of cliff. The surface of the peninsula is rocky, and has but a thin covering of soil, and a scanty herbage. At its northern extremity it is deeply indented by a bay, which thus divides it into two promontories; the more westerly of those is called Ramore Head. On the south the connexion of the rocks with the mainland is concealed by a tract of sand which occupies the isthmus, and extends in a level beach nearly two


S K E R R I E S
Western Skerry
Wankle Isle
Castle Isle
Eastern Skerry
Port Rush
Quarry
Harbour
Portrush Rock
Greenstone

shore from the commencement of the sandy beach to the distance of three furlongs to the N.W.; in the middle part of the peninsula it is covered partly by vegetation and the buildings connected with the village, but on the S.W. it is seen in section in the cliffs facing the harbour, in which a quarry has been opened to procure stones for the breakwater. A perpendicular front of 50 feet in height, and 60 yards in length is thus presented. The upper part of this cliff, to the depth of nearly four feet, and in some places 6 or 7 feet, is composed of the Portrush rock—the remaining portion, to the level of the water, being the ordinary large-grained greenstone. The two rocks are, in every part, beautifully contrasted; the small grain and dark green colour of the one, shewing strongly in relief beside the coarse and granitic texture of the other. It was the examination of this spot in the summer of 1832, for it is of that period I speak, (subsequent operations may have considerably altered the appearances,) that first convinced me that the greenstone was the inferior instead of the superior rock, as has been generally stated. An investigation of the peninsula, with this new light thrown upon the subject, showed that wherever the two rocks occur together, this same relative position is maintained. The average thickness of the Portrush rock over the peninsula is from 4 to 5 feet.

4. Passing into the Skerries, the same rock again presents itself overlying the sienitic greenstone, of which the lower part of those islands is composed. It covers almost all their southern and sloping sides, and rising along the inclined plane towards their summits, it terminates abruptly where their surface breaks down in steep escarpments towards the north. The greenstone rises from beneath it, and constitutes the highest ridge of the isles, all their northren front, and the lower ledges of rock, over which the tide rises on that side. The details will be found in the accompanying map and section. In some places on the S.W. side of the eastern isle, or great Skerry, as it is called, the rock appears in isolated patches, the ordinary trap rock forming the ground between, from which the other has been worn away. In the eastern part of the same island this rock attains the greatest thickness which is anywhere observed, namely 8 feet, the average thickness over these islands not exceeding 5 feet.

5. In most parts of the area now described as occupied by the interesting rock under consideration, it presents a distinct stratification, while it dips in general a little N. of E., conforming to the inclination of the surface on which it is placed. The following are the inclinations and dips at five nearly equidistant points along the shore of the peninsula, commencing

at the eastern end:—24° N. of E. at 17°; 24° N. of E. at 18°; N.E. at 12°; 25° N. of E. at 10° to 12°; 25° N. of E. at 9°. The dips are reckoned to the true, not the magnetic north.* On the Skerries the dip is nearly south of the same small angles. The strata are generally from two or three inches to a foot, or a foot and a half thick: they are frequently broken across by rents and fissures, intersecting one another at right angles, and giving to the surface the appearance of being diced into squares. The arrangement strikes the eye at once as being very distinct from that of the greenstone; indeed, so well marked is this difference, that before visiting the Skerries, I was able to see with the naked eye, from the opposite shore, that this same rock constituted the southern shore of these islands. In some places, however, no traces of stratification appear, as in the section facing the harbour; here no line of division can be seen, and the whole has very much the appearance of a mass of tabular basalt. At their junction the two rocks generally adhere firmly, but in some places there are fissures by which they are separated.

The two rocks frequently alternate or are repeated, the one after the other, in a vertical section. These alternations are seen in several places along the shore of the peninsula, particularly at its eastern extremity, where the rock rises from the sandy beach—here the alternating strata seldom exceed a few inches in thickness, but they are always perfectly distinct in structure, the constant intermixture of the thin layers never producing confusion, nor obliterating the character of either, unless when those of the fossiliferous rock undulate in their course, in which case they are so much altered as to resemble the greenstone. In these waved strata, there are often contained subordinate veins of the trap and Portrush rock intermixed, so that the distinction of substances is hardly traceable. In some cases, small veins of the latter rock interposed in the trap, thin out and terminate before traversing the entire mass; and an instance occurs, where a vein terminates in a point in a bed of greenstone at one end, and at the other is connected with the main body of the parent rock—indeed, it is probable, that most of the layers interstratified with the trap, have a similar origin, though the connexion cannot be made out in the present position of the rocks.

At one spot on the Skerries similar appearances are observable: at their junction near the summit of the Castle island, the two rocks are intermixed, as if the substance of the one rock had been pervaded by the other.

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*Mr. Griffith in his annual address, has estimated the dips for the magnetic, and not the true north; he has, consequently, been led into a slight error. This cause of confusion should be carefully avoided.

6. The shells which occur in the Portrush rock belong to the genera ammonites unio and pecten, all shells of the lias; the species have not been determined, for they are rather casts than perfect shells, the forms, in most cases, being nearly obliterated. They are more abundant in the eastern corner of the peninsula than in any other place, and here they often occur in the layers interstratified with the trap. Iron pyrites abound in this rock, and often cover over the impressions of the shells; it contains also hornstone in thin veins—calcareous spar in veins, and irregularly disseminated—and spheroidal masses of a bluish grey substance resembling chert. But the most interesting mineral contents of this rock are some members of the zeolite family. In one place, where a vein of the rock runs into the greenstone, fibrous mesotype, which is so common in in our trap rocks, traverses the vein from the greenstone on one side to the greenstone on the other. At another place, where no trap is near, seams run in all directions through the fossiliferous rock, and contain well-defined crystals of stilbite. Stilbite occurs also in veins in the same rock at one place in the Skerries. The occurrence of the former mineral may be accounted for by infiltration from the overlying trap through the vein; but the same explanation cannot be offered for the latter, unless we suppose that the rock had, in this place, been formerly covered by trap, which was afterwards worn away.

The occurrence of zeolites in an igneous rock, under circumstances precisely similar to those we have been describing, is mentioned by Mr. Lyell, (vol. iii. p. 81. 1st edit. and vol. iii. pp. 427, 428, 4th edit.) Speaking of the intrusion of beds of lava among the newer pliocene strata of the isle of Cyclops, he observes, " The arenaceous laminae are much hardened at the point of contact, and the clays are converted into siliceous schist........ The pores of the lava are sometimes coated, or entirely filled, with carbonate of lime, and a zeolite resembling analcime, which has been called Cyclopite. *The latter mineral has also been found in small fissures traversing the altered marl, shewing that the same cause which introduced the minerals into the cavities of the lava, whether we suppose sublimation or aqueous infiltration, conveyed it also into the open rents of the contiguous sedimentary strata.*"

7. Before stating any opinion respecting the nature of this curious rock, it will be proper to bring forward the views of the distinguished geologists by whom it is referred to.

Dr. Richardson, speaking of the Portrush rock, (Irish Trans. vol. 9, p. 28,) says, " The nature of this stone is not yet fully ascertained. Sir Joseph Banks informs me that the specimens I sent him are pronounced by his friends not to be *genuine* or *legitimate* basalt. An eminent Scotch geologist who visited the spot last summer, I am told, asserts this stone to be chert petrosilex, or schistus."

On the other side, Mr. Kirwan, to whom I gave specimens, asserts in a late publication, that it is basalt; our ingenious Mr. Higgins is of the same opinion; and the celebrated professor Pictet, of Geneva, who did me the honour of a visit last summer, considers it to be basalt, containing a greater portion of silex than usual. I believe Mons. Pictet is right. In a subsequent paper in the same volume, he enters at length into the refutation of the views of Mr. Playfair, to be given in the next extract; but these controversies are now matters rather of literary curiosity than scientific value.

Mr. Playfair's view is given in vol. 1st of his work, p. 289. "Another fact, which has been much insisted on of late, in proof of the aqueous formation of basaltic rocks, is, that shells are found in them. Of the reality of this fact, however, or at least of the instances produced, great doubts, I think, may be reasonably entertained. The specimens of the supposed basalts with shells included in them, that are chiefly relied on, are found at Portrush in Ireland, a rocky promontory to the westward of the Giant's Causeway, and separated from it by a considerable body of calcareous strata. Some of these specimens were brought to Edinburgh about a year ago, and were supposed, I believe, to contain an irrefragable proof of the neptunian origin of the basaltic promontory where they were found. I went to see these specimens in company with Lord Webb Seymour and Sir James Hall; and on examining them carefully, we were all of opinion, that the stones which contained the shells, were no part of the real basalts. They were all very compact, and had all more or less of a siliceous appearance, such as that of chert; they had nothing of a sparry or crystalized structure, their fracture was conchoidal, and but slightly uneven. In two of them, one of which bore the impression of a cornu ammonites, the schistose texture might be distinctly perceived. A specimen which accompanied them, but in which there was no shell, served very exactly to explain the relation between these stones and the true basaltes. Part of this specimen was a true basalt; and the rest a sort of hornstone, exactly the same as that in which the shells were, and not unlike the jasper that is under the whinstone of Salisbury crag, and in contact with it; so that, on the whole, it was evident, that the rock containing the shells is the schistus or stratified stone, which serves as the base of the basaltes, and which has acquired a high degree of induration by the vicinity of the great ignited mass of whinstone."

This solution of the difficulty has since been confirmed by observations made on the spot by Dr. Hope, who discovered two or three alternations of the basaltic rock, with the beds of the schistus in which the shells are contained.

Some years after this was written Mr. Playfair visited Portrush, and in a letter to Dr. M'Donnell of Belfast, who has communicated this fact to me, expresses his entire conviction of the accuracy of his original conjecture.

Mr. Conybeare in his notes on the coast section appended to Dr. Berger's paper on the N.E. of Ireland (Geol. Trans. vol. 3. p. 212,) has the following remarks on this rock:—"The peninsula of Portrush, which may be about a mile in circumference, is fenced with low cliffs on the west, north, and east; those on the west present a rude prismatic greenstone, those on the north and east, tabular masses of greenstone overlying, and in some places appearing to alternate, with a very remarkable rock. It is a flinty slate, exactly similar to the indurated slate clay, which forms the wall of the Carrick Mawr dike, in the Ballycastle collieries; and the analogy is rendered the more striking from the further resemblance of the greenstone of that dyke to the greenstone of these cliffs. In this flinty slate are contained numerous impressions of cornu ammonites invested with pyrites, the shells being similar to those found in the slate clay underlying the chalk near Ballintoy, and we felt convinced, while examining the spot, that the rock was no other than the slate clay of the lias formation in an indurated state."

8. Now, that the igneous origin of the trap rocks is so clearly established, no one thinks of adducing the Portrush rock as a proof of aqueous deposition, and therefore, in conformity with the views of professor Playfair and Mr. Conybeare, the rock is generally set down as a lias clay indurated. Though a firm believer in the igneous theory, I have several objections against this view. 1st. This rock *overlies* and *does not underlie* the greenstone: we have no instance in the North of Ireland of a trap rock underlying any of our secondary rocks. It covers chalk, new red sandstone, and the coal formation. It cuts them through in vertical walls, and is transfused among them in disconnected masses, but never supports them as a foundation rock. 2nd. At the eastern extremity of Portrush strand, the chalk sinks to the level of the sea, and seems to dip under it. It does not appear again till we arrive at the headland of Magilligan, 8 or 10 miles distant, where it gradually emerges towards the west from the sands that here

form the shore. Now, we have no reason to believe that the chalk is here broken off, or that its continuity is ever interrupted, unless when it comes in contact with columnar basalt; but, on the contrary, every reason to conclude, that its edge merely suffers a depression, and, consequently, that the greenstone which underlies the Portrush rock, really covers the chalk. The Portrush rock, if this view be correct, will be far indeed removed from the position of the lias clay. 3d. The occurrence of zeolites, which are only found in igneous rocks, seems to render it improbable that the rock is lias clay. Trap is often found in absolute contact with chalk, greensand, and many other secondary rocks, but no instance has ever occurred to me of any mineral of the zeolite family being found in any of these, or passing into them from the adjacent trap. These objections appear to possess considerable weight. Still, however, they are not sufficient to overthrow the received opinion. It is possible that the underlying greenstone may be a huge sheet spread out under or between the beds of lias, the chalk being entirely broken off; in which case, the district will form a remarkable exception to the structure of the North of Ireland.

The alternations and veins that have been described, clearly show the injection of one of the rocks into the other, and will admit of explanation whichever of the two we suppose to have been injected; but they appear more consistent with the hypothesis of the irruption of the Portrush rock among strata which had not acquired complete consolidation. Mr. Bakewell (Geol. 4th edit. p. 210,) observes, that " The occurrence of organic remains enveloped in basalt, of which there are various instances, may admit of an easy explanation, if we allow that basalt has once flowed like lava at the bottom of the ocean. Modern lavas often envelope bones and other substances that they meet with in their course."

If we suppose our Portrush rock to have been formed in this way, it is plain that it must have been erupted, at the latest, in the cretaceous period, chalk being the newest rock in which ammonites are found.

9. The facts that have been now stated will perhaps, enable some member of the society to draw conclusions more positive than any to which I have arrived.

POSTSCRIPT.

In the anniversary address delivered on the 11th Feb. 1835 and soon after published, the President, Mr. Griffith, in reviewing the papers read during the session, of which the present memoir was one, entered at some length into the question of the age of the Portrush rock, with the intention of removing the difficulties stated in the beginning of article 8. In quoting from that article, Mr. Griffith has overlooked the last sentence, in which an opinion is expressed, that notwithstanding the objections brought forward, *the rock can be no other than lias clay;* and that the underlying greenstone is a *stream injected horizontally among the strata.* In consequence of this omission, he has argued the question as if I considered that the rock could not be lias clay—an opinion which I never entertained; the only difficulty was the position of the rock in respect of the chalk. This difficulty has been nearly removed by a discovery which we owe to Mr. Griffith. He has found chalk about a mile S.E. of Portrush, considerably to the west of the White Rocks. The strata dip to the S.W. and conformably to the dip of the Portrush rock on the Skerries. He has shown that the bottom of the intervening channel is composed of stiff blue clay, resembling lias clay; and from these facts he concludes, that the Portrush rock occupies the usual position of the lias. The existence of the chalk at this place certainly explains the principal difficulty stated in article 8. From its position there can be little doubt that it ranges across the low country, south of Portrush, until it sinks below the level of the sea at the commencement of the cliffs which occupy the coast from the S.W. termination of Portrush strand, to near the mouth of the River Bann; and that it does not dip below the sea level at the eastern extremity of Portrush strand, as I formerly stated, when ignorant of its being found in this locality. It is clear, therefore, that the underlying greenstone is not superior to the chalk, but that it is a great stream or sheet of trap thrown horizontally under and among the lias strata. This is my own first conjecture, and it is one with which Mr. Griffith's observations have led him to agree.

From what has been now said, I think we may fairly consider that the position of this long disputed rock has been finally fixed; and its identity with lias clay fully established.

ON THE MAGNESIAN LIMESTONE AND ASSOCIATED BEDS WHICH OCCUR AT HOLLYWOOD IN THE COUNTY OF DOWN.

BY JAMES BRYCE, JUN. M.A. F.G.S. &c.

(Read April 8th, 1835.)

1. The new red sandstone which every where encircles the great trap district attains a high degree of developement in the valley of the Lagan. It passes in its upper part into argillaceous and gypseous marls, and occasionally gives origin to salt-springs. Rising to a considerable height on the face of the Belfast Mountains, it is succeeded by the upper secondary deposits, lias greensand and chalk, which are well known as constituting the base on which the basaltic rocks repose. Its middle part consists of sands and variegated sandstones, sometimes slightly calcareous. It occupies the shore of Belfast bay on the north, as far as its entrance at Whitehead. On the southern side of the bay it extends over the low grounds between the shore and the Hollywood hills. These are the north-eastern edge of the great zone of greywacke slate which traverses Down and the adjacent counties to the west. Preserving their usually high inclination, and the bearing they generally possess, the strata of this rock range along these hills to the north-east, and intersect the shore of the bay at Craigavad, about two miles below the village of Hollywood. Owing to the inclination of these hills to the line of the shore, the space occupied by the sandstone gradually narrows from the head of the bay to the east, until it terminates in a point at Craigavad. It is in the lower and narrower part of the area occupied by the sandstone that the magnesian limestone appears.

2. From Belfast to Hollywood, the immediate shore presents no sandstone, being every where covered by a deep deposit of alluvial matter. That rock first appears on the eastern side of the village: here it extends over the space usually covered by the tide, and rises into a steep bank or low cliff, which serves as a limit to high water, and which stretches with little interruption along the shore, as far as Craigavad. Over all the space between this bank and low water mark, and in the adjacent beds of the rivulets descending from the hills, the sandstone is seen in distinct strata, dipping towards the sea at an angle varying from 30° to 35°, and rising towards the land in successive layers, which trend parallel to one another along the shore, and are separated by troughs or trenches filled with sand and mud. The strata are generally thin, the colours are red, bluish grey, and light yellow, the two former being pre-

dominant. The rock is generally of a uniform structure, consisting of cemented grains of quartz, with numerous spangles of mica ; but it sometimes contains a considerable admixture of argillaceous matter, which gives it an earthy aspect. As the area occupied by this rock gradually narrows to the eastward, it is plain that as we advance towards Craigavad the inferior strata next the greywacke will crop out on the shore ; accordingly in this part a conglomerate appears—it consists of rounded pieces of quartz and greywacke imbedded in a coarse cement of sand and clay. The fragments of greywacke are generally larger than those of the quartz, but neither of them attains to any great size—small fragments of a yellow and earthy carbonate of lime, and a grey crystalline limestone, are often found in the conglomerate; the base itself frequently effervesces briskly with acids. As the imbedded limestone is most probably magnesian, the rock may be called a Dolomitic conglomerate. In the same part of the area under consideration, some portions of the strata are a conglomerate of quartz pebbles, while the adjacent portions preserve the character of a fine-grained freestone. The sandstone and greywacke have never been detected here in immediate contact, but it is probable that all the lower beds are conglomerate, as we find in several places on the southern side of the valley of the Lagan, that the inferior strata of new red sandstone, pass into a coarse earthy conglomerate of quartz and greywacke. But it is only in the place already described, that the imbedded fragments of limestone are found.

On the western side of Cultra quay, a blue slate is interstratified with the sandstone. It is soft and friable, and feels unctuous, probably from its intermixture with magnesian earth. It effervesces briskly with acids, and may therefore be denominated a marl-slate. It is not bituminous.

A few perches west of Cultra-quay the sandstone dips from 10° to 30° east of north, by the compass—about half a mile to the east of this it dips 10° west of north—in the intermediate space the dip is either north or a few degrees east of it. It is within this space that the magnesian limestone is found ; it would therefore appear to have been deposited in a basin-shaped hollow. Over all this space the limestone alternates with the sandstone, and of course has the same dip and inclination ; the alternations are many times repeated between the bank already mentioned and low water mark, the successive layers running along the shore parallel to those of the sandstone before described, and separated from one another by the elevated end of a stratum of sandstone. The beds of limestone vary in thickness from an inch to one foot and a foot and a half. The upper surface of the limestone strata, where exposed by the wearing away of the sandstone from above them, are frequently divided by rents or seams running in various directions along the surface, into squares, hexagons, trapeziums and other irregular figures, which gives the rock, when viewed from above, a columnar aspect. In general, also, these pieces present a convex surface.

3. By far the greatest quantity of this rock is compact and fine-grained, of a grey or bluish grey colour, resembling very closely those compact varieties of lias used for lithographic purposes. It is sometimes of a light yellow or buff colour, and there are several strata of a grey colour and open crystalline texture, very like carboniferous limestone, or the coarser varieties of lias. It has an arenaceous appearance and is most probably much mixed with sand. The buff coloured variety is that which has been most used for economical purposes. I am informed by Dr. M'Donnell, that considerable quantities of it were sent many years ago to England by Mr. Kennedy of Cultra, to have its magnesia extracted; that the grey variety has never been employed for this or any other purpose; and that as Mr. Tennant and other distinguished chemists visited Mr. Kennedy at Cultra, and examined the limestone, it is probable that he employed only that which appeared to them to contain magnesia; it is, therefore, most likely that little of that earth will be found in the grey variety. The yellow magnesian limestone dissolves slowly in acids, and effervesces feebly. A specimen of it, analysed some years ago by a chemical friend, yielded the following ingredients :—

Carbonic acid	47.26
Lime	30.26
Magnesia	16.25
Peroxide of iron	1.50
Manganese	1.60
Water	1.13
Loss	2.00
	100.00

This analysis is not given with much confidence; it is highly desirable that an accurate examination should be made of the several varieties.

Organic remains are extremely rare in this formation, as they generally are in magnesian limestone. The only fossils found were a few minute *terebratulae* or *productae*.

4. It is an important part of the duty of the geologist, in giving a history of the rocks of a particular locality, to endeavour

to identify them with similar formations in other countries. In this, however, great caution is required—it is not only often difficult, or impossible, but even inconsistent with all just views of the mode of formation; and much mischief has been done in geology by attempting to establish it in every case. In the present instance the facts brought forward in the preceding paper had been all observed, and the paper written thus far before the idea occurred of attempting to identify, except in a very general way, so insignificant a deposit as that now described with formations in foreign localities. On examining attentively the extremely valuable and well written memoir of Professor Sedgwick, on the magnesian limestone of the north-east of England (Geol. Trans. New Series, vol. 3, part 1,) which had been hastily looked over six years before, the author perceived a very striking resemblance between several of the beds there described, and those occurring in the area under consideration. Indeed, so close does the resemblance appear to be, that he has not hesitated to arrive at what he considers a curious and interesting conclusion—that a series of beds occurs in this insignificant spot, at Hollywood, not more than half a mile long, and less than a quarter of a mile broad, which are the exact equivalents, in relative position and mineral structure, of deposits which occupy in the East of England, a space 200 miles long and from 5 to 20 broad, and on the continent of Europe areas still more extensive.*

The conglomerate and sandstone which have been described as inferior to the magnesian limestone, and occupying the space between it and the greywacke, agree very closely in character with the "inferior red sandstone" of Professor Sedgwick (pp. 64–75 of his Memoir.) They were at first thought to be the equivalents of the dolomitic conglomerate of the south-west of England; but in the memoir referred to the latter is shown to have a representative in the superior beds of the series in the north-east of England. Our conglomerate seems perfectly identical with the calcareous conglomerate of the west of England, described by Mr. Murchison in a very recent paper to the Geological Society, London, and of which an abstract only has been yet published. The blue slate which has been described as interstratified with the sandstone, is the equivalent of the Professor's "marle slate" (pp. 75–80,) and our grey compact limestone is identical with the "thinbedded nearly compact limestone, frequently without magnesia," which is associated with this marl slate (pp. 75–81.) The "arenaceous dolomite," (pp. 82–83,) seems also to have a representative in one of our beds, the coarse sandy and semicrystalline limestone; but this is affirmed with less confidence. The very partial developement of the yellow magnesian limestone in our little area, deprives us of any term of comparison with the upper beds of the great English series. We want another link in the chain of comparison, in the absence of the carboniferous rocks on which the whole English formation reposes. No rock of this order has yet been found in the neighbourhood of the magnesian limestone. If any such exist, they are probably at a great depth under the bay, and are thus overlapped by the red sandstone series resting on the older rocks. Still, that the deposit just described is posterior in age to the carboniferous period there cannot be a doubt, from the facts that have been stated as well as from the unbroken passage into the upper red sandstone with its gypseous and saliferous marls.

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* The sandstone on the northern shore of Belfast bay is calcareous, but I have not been able to determine whether it contains any magnesia.

5. Professor Sedgwick has identified his "inferior red sandstone" with the *todte liegendes* of Germany; if the conclusions just arrived at with respect to the age of the deposit now described, be correct, it will follow that our lower sandstone is the equivalent of the celebrated *Todte liegendes*, our blue shale and grey limestone of the *Kupfer Schiefer* and *Zechstein*, and our upper red sandstone and gypseous marls of the *Keuper* and *bunter sandstein*, the *Muschelkalk* being absent with us as in England, and the *rauchwaucke* being represented only by our partial and unimportant formation of yellow limestone.

6. In the small area that has been described there are less than nine whin dykes that traverse the different strata; the bearing and width of these are laid down on the accompanying map. Their intersection with the sandstone, limestone, and shale is well exhibited: and a decided alteration is produced upon those rocks along the line of contact; the sandstone is highly indurated, and is often divided into parallel bands, probably from the partial separation of the sandy and argillaceous particles. The limestone is also rendered harder than usual, and sometimes exhibits a coarse crystalline structure; its colour is frequently changed to blue, perhaps the effect upon the manganese it contains. But the most striking effect is produced upon the shale, which, indeed, from its soft and friable nature, is most favourable for exhibiting an alteration. The great dyke at Cultra quay, which is 18 feet wide, cuts through this shale and converts it into flinty slate or Lydian stone, very closely resembling the celebrated Port-

rush rock, to which the attention of the society was called in a late memoir. The induration extends to the distance of two or three feet from the dyke The marl slate in its ordinary state effervesces with acids—these indurated specimens do not; which would lead to the inference that the effect of the heat has been to expel the carbonic acid, and that consequently the trap rock has been erupted under no great pressure. We find, however, that the limestone in contact with some of the neighbouring dykes, still retains its carbonic acids; which completely neutralizes any conclusion that might be drawn from the other phenomenon.

It is worthy of remark that there are whin dykes on the opposite, or Antrim shore of the bay, on the lines where these might be expected to appear, and there can be no doubt that the continuity of each is preserved over the intermediate space and much greater distances.

In conclusion, it may be observed that the name magnesian limestone ought to be applied only to deposits of the age described in this paper, and not to dolomitic beds of the mountain limestone, as is frequently done—the use of such language can only lead to error, and introduce confusion where perfect order should reign.

DESCRIPTION OF A LIMESTONE DISTRICT ON THE N.E. SHORE OF CARLINGFORD BAY, AND OF LITTORAL DEPOSITS OF SHELLS AND LIMESTONE, &c. &.

BY MAJOR S. PATRICKSON, M.G. S. D.

(Read January 14, 1835.)

During the past summer, accompanied by Lieutenant James, R. E. I examined the mountain limestone district which is included between Green Castle and Cranfield Point. Its first outcrop near the former place is curious, and I believe, uncommon in character. The strata strikes east and west, and dips to the south at an angle of about 30°.

On a first view of this formation, it would appear to be granwarke or conglomerate resembling the old red sandstone; but on closer examination it proves to be a limestone conglomerate. Some of the strata are wholly of this character, others partly, passing gradually into the regular texture of the limestone. A variety of rounded and angular masses of rocks cemented by carbonate of lime, form this conglomerate.

There was difficulty in procuring a specimen of this conglomerate containing a perfect shell, but fragments of this description may be observed on a close inspection. The gravel and stone, into which it passes, abounds in zoophites and shells, as do all the other outcrops which appear in succession along the shore.

The accompanying map, for which I am indebted to Lieutenant James, R. E. will point out the positions and dip of these outcrops, which are at great variance.

The strata are cut through in three places by dykes, but are not in any respect disturbed.

A small quarry of this limestone is at present worked, near Soldier's Point. It is inland about 40 yards from highwater mark, and it abounds in shells and encrinites.

At Cranfield Point, large flat slabs of limestone appear projecting from the base of the cliff, which I should suppose were "in place," although much disturbed. There are large strata of the same limestone forming a sort of Pier to protect boats at this point, which I was informed were taken from the shore under this cliff. This limestone has abundance of shells, &c. &c.

Twenty feet of stratified sand and gravel, with clay, containing large water-worn fragments of rocks, form the bank, or cliff, containing the limestone slabs above alluded to, and within two feet of the surface a stratum of littoral formation, about 18 inches thick, appears. It is composed of rolled masses of limestone, perforated by lithodomi, rounded stones of other descriptions, and littoral shells of existing species. There is an exact resemblance between this ancient deposit and the modern beach which is at the base of the cliff.

The eastern side of this point, on which the old light-house rests, furnishes two more examples of marine deposit.

The cliff is about 18 feet high, formed of strata of exceedingly fine sand, (with a few rounded masses of stone and gravel thinly scattered through the mass,) passing into dark coloured clay at its base, from which, at the elevation of 12 and 17 feet, two small seams of littoral shells are seen. Some of the shells are in good preservation, but in general they fall to pieces shortly after removal from the sand.

In a N. W. direction from the old light-house, a system of sand-hills commences (covering a considerable surface, and in some places elevated about 20 feet above the sea level) to skirt the shore to Soldier's Point. Marine shells of existing species are found in great plenty in these sand-hills. The cultivated part of this neighbourhood is divided by walls, in great part formed by water-worn limestone, perforated by lithodomi, which, it is not probable, were brought from the shore.

From these examples of marine deposit, we may reasonably conclude, that a considerable extent of this territory has at some distant period formed the bed of a sea.

The limestone formation appears to be of considerable extent. The Block-house Island, distant about one mile from Soldier's Point, is formed of it; and at low water, several reefs of this rock shew themselves at the distance of one or two miles to the S. W. These reefs are quarried for lime. The rock is a perfect honey-comb from the perforation of lithodomi, and a white deposit, of exceeding close texture and toughness, covers every part of the rock, unoccupied by adhering serpulæ, and other shells.

It effervesces strongly on application of an acid, and may be therefore considered carbonate of lime.

A DESCRIPTIVE LIST OF THE DYKES APPEARING ON THE SHORE WHICH SKIRTS THE MOURNE MOUNTAINS, AND NUMBERED FROM THOMAS' MOUNTAIN NEAR WARREN POINT.

BY MAJOR S. PATRICKSON, M. G. S. D.

(Read January 14, 1835.)

No.	Breadth of Dyke in Feet.	
1	7	Hornblende, the dyke dips to the south.
2	8	A Cornean, containing crystals of quartz, separates a large bed of porphyry from the schist.
3		Cornean ⎫ Cross a large bed of porphyry which contain masses of snow-white compact felspar, crossed by minute veins of grey quartz (see specimen A.) There is a cave in this bed of porphyry, where twin crystals of felspar are found decomposing.
4		Do. ⎭
5	12	Hornblende rock.
6	44	Trachytic porphyry. This dyke varies much in colour, the felspar appearing in many shades of red and white. A small branch dyke is thrown off at an angle of about 20°, which, at a short distance from the parent dyke, changes to a compact hornblende. Small dykes of hornblende run down the

No.	Breadth of Dyke in Feet.	
		centre of this great dyke, and resemble lava streams. It also contains masses of felspar.
7	1½	Cornean. Rounded masses of quarts, and other minerals fill the small cavities which have been in it. It runs in a Serpentine form.
8	3½	Greenstone.
9	3	Compact greenstone, with crystals of felspar.
10	9	Greenstone.
11	4	Hornblende, containing quartz with molybdena, William's Harbour.
12	4	Hornstone porphyry.
13	12	Hornblende.
14	6	Lydianstone.
15	4	Lydianstone with felspar.
16	5	Hornblende.
17	10	Hornblende Slate.
18	8	Compact greenstone, with a branch passing into variolite.
19	21	Rock with kirwanite.
20	3	Rock with mournite.
21	7	Columnar greenstone with quartz.
22	3	Greenstone in parallel contact with No. 23.
23	23	Porphyry with Labrador felspar. This dyke encloses crystals of felspar four inches in diameter.
24	4	Greenstone in parallel contact with No. 23, (specimen lost).
25	4	Greenstone
26		Cornean, structure camillar.
27	6	Variolite.
28	6	Cornean, with various minerals and a crystal of molybdena.
29	4	Lydianstone.
30	2	Variolite.
31	6	Hornblende rock with kirwanite.
32	6	Lydianstone, with minute globules of felspar; also dark brilliant crystals only discernible by the microscope.
33	12	Lydianstone.
34	8	Do.
35	4	Partly columnar clink-stone.
36	2	Lydianstone.
37	4	Lydianstone.
38	3	Columnar, resembling variolite.
39	4	Lydianstone—vesicular, the cavities, filled with a

No.	Breadth of Dyke in Feet.	
		white mineral, having a dark spot in the centre resembling variolite.
40	4	Variolite.
41	9	Compact greenstone with kryolite or albite.
42	6	Compact greenstone, with crystals of felspar.
43	2	Hornblende.
44	5	Greenstone.
45	7	Greenstone.
46	15	Lydianstone, branching off at an angle of 10°.
47		A hornblende dyke in parallel contact with No. 48.
48	30	A porphyritic dyke, ¼ mile N. of Mullertown, it is sometimes hid by the sea in shifting the shingle. The porphyry appears at *a*, but unaccompanied by the two dykes of hornblende.
49		A hornblende dyke in parallel contact with 48.
50	7	Greenstone with felspar.
51	4	Hornblende.
52	7	Hornblende, north side of Analory quay.
53	1	Columnar greenstone.
54	2	Columnar greenstone.
55	7	Lydianstone.
56	2	Compact greenstone bordering a dyke of urite.
57	16	Urite veined with hornstone.
58	6	Compact greenstone bordering No. 57.
59	7	Greenstone.
60	16	Porphyry.
61	9	Greenstone.
62	7	Columnar whitestone.
63	11	Hornblende, columnar and hollow.
64	7	Greenstone porphyry.
65	5	Greenstone in a zig-zag.
66	6	Greenstone.
67	9	Greenstone.
68	⅓	Cornean with minute crystals of felspar, veins of chalcedony, and a mineral in transparent crystals, which scratch quartz.
69	6	Fine-grained vesicular greenstone.
70	8	Greenstone, with circular cavities filled with oxide of iron, and surrounded by pyrites. These three last dykes pass through the mountain limestone at Soldier's Point.
71	3	Greenstone-vesicular cavities filled with felspar, having a nucleus of carbonate of lime—also quartz.
72	3	Greenstone porphyry with particles of glassy felspar.

No.	Breadth of Dyke in Feet.	
73	6	Porphyritic greenstone with mournite.
74	3	Dark hornblende with mournite assuming the spheroidal form.
75	8	Porphyritic greenstone with mournite and lydianstone attached.
76	4	A dyke composed principally of mica in crystals with small fragments of pink felspar, cemented together by hornblende—decomposes rapidly, and assumes the globular form. It appears again about ¼ mile to the eastward.

REMARKS ON THE TRAP ROCKS WHICH OCCUR IN THE VICINITY OF LIMERICK.

BY JOHN SCOULER, M.D. F.L.S. &C. PROFESSOR OF MINERALOGY, ROYAL DUBLIN SOCIETY.

(Read January 13th, 1836.)

Trap rocks are, as is well known, of frequent occurrence in Ireland, and exist under many interesting modifications of character, and present important differences with respect to their origin. In the vicinity of Dublin and in the county of Wicklow trap and porphyry are by no means rare; they occur in imperfectly stratafied masses, which have sent no veins into the adjacent strata, nor produced any dislocations nor any changes of a chemical nature on the surrounding rocks. In short, they graduate into argillaceous schist, and are therefore altered rocks bearing the same relation to the ordinary schist which granular gneiss does to the schistose, with which it is associated. In the North of Ireland the trap has been erupted while in a state of fluidity, as is proved by its veins and overflowing beds, while it is probable, that in the county of Limerick, the trap has been elevated in a solid state, since, although it has deranged the calcareous strata, and changed portions of them into compact crystalline limestone, it has nowhere, in as far as I could ascertain, either sent forth veins of liquid matter or spread in sheets over the country.

As the trap district of Limerick has been described by Mr Weaver, and has also been the subject of two communications to this Society, it will be unnecessary to repeat the details, which are already well known to all, although frequent reference will be made to them in the present paper.

The country around Limerick consists of carboniferous limestone, possessing the usual properties and containing the organic remains which characterise that rock. The limestone reposes on sandstone, and their juxta position may be studied in many localities; as in the hills of Clare on the north side of the Shannon, at Knockferna, and various other situations. The sandstone reposes on rocks possessing the external characters of argillaceous schist, and whose age it is at present unnecessary to determine. The the trap rocks therefore have in every case protruded through the limestone, and the region in which they occur is bounded by hills of sandstone and schist.

The trap occurs in detached and unconnected masses, scattered over the country which are so numerous, that much time and labour would be required to enumerate the whole of them, and probably several are yet to be detected. About twenty portions of trap may be enumerated, distributed over an area of about 20 miles in length by 8 in breadth. The following is an enumeration of the more important of them, Carrig O'Gunnel, Newtown Hill, Cahir Parry, Herbertstown, Knockferna, Pallas Green, Kiteely, Cahirconlish, Mount Rice, Loch Gurr.

These trap rocks present several remarkable features which distinguish them from those of the North of Ireland, and appear to indicate that, although in both cases we must admit their igneous origin, they differ in several important circumstances. As already stated, the traps of Limerick have not spread over the strata to any great extent, nor have I been able to detect a single vein cutting through the limestone. The absence of amygdaloids and of all zeolitic minerals has already been remarked by Mr. Weaver. Another circumstance by which the trap of Limerick is distinguished from that of Antrim, consists in the great abundance of trap breccias containing numerous fragments of limestone and organic remains, which everywhere surround the axis of homogeneous trap.

To give a more accurate idea of these phenomena, it will be necessary to describe with more detail some of these masses of erupted rock:

The first case to which we shall allude, occurs at Carrig O'Gunnel, situated about four miles to the west of Limerick, and easily recognised by its picturesque and ruined castle. In the immediate vicinity of the rock on which the castle stands, we find a series of low hills or rather mounds, composed of a breccia, consisting of fragments of trap and limestone with abundance of organic remains. The study of this breccia is extremely interesting. That portion which is most superficial and forms the external crust of the hill is of a beautiful green colour, resembling some varieties of serpentine, with stems and branches of Crinoidea, &c. disseminated through it. This paste appears to be an intimate mixture of trap and limestone, in which the eye cannot easily recognise the component parts. In the paste we observe fragments of limestone, which are compact and resembling marble, but their origin is undoubted, as they contain shells of Terbratulæ and portions of Encrinites, proving that they are altered portions of the carboniferous limestone. The breccia, when it is nearer the centre of the hills, passes into an extremely compact rock, abounding in lime, in which all distinct outline of the fragments is lost, and their situation in the rock is only indicated by blotches of a different colour from the general mass. The only fragments visible in this breccia are those of trap and limestone. No portions of other rocks, not even of sandstone, were detected in a single instance, nor did the limestone or trap bear any evidences of transportation.

In these low hills the trap nowhere appears at the surface; but in the more elevated rock on which the castle stands, we find this rock has protruded through the strata. This mass of trap is surrounded at its base by the breccia which we have described, and of which a portion is also found on its summit; but on examining the rock more attentively, we find that its axis consists of a homogeneous and simple trap rock, consisting of an extremely fine aggregation of black augite and felspar, and perfectly free from all brecciated matter.

The second example which we shall select is taken from Cahir Parry, situated about six miles to the east of Limerick. Near the little church of Cahir Parry a quarry has been opened, where the trap assumes a columnar form. About a quarter of a mile beyond the church, and on the opposite side of the road, there is a woody hill, whose sides are covered by the usual trap breccia. At the base of this hill we find that, fortunately, a quarry has been opened very near the junction of the trap with the limestone. The limestone cannot be many yards distant from the trap, although their actual contact cannot be seen. The limestone is covered for a small extent, not by the simple trap, but by the breccia; and the phenomena are extremely curious. The limestone is destitute of organic remains; all traces of stratification have disappeared; and the limestone is highly crystalline, forming a beautiful pink-coloured marble. The changes produced on the limestone do not extend beyond a few yards from the trap.

The limestone is covered by a bed of breccia about twelve feet in thickness, which presents a great diversity of character, consisting of seams of wacke and breccia. By wacke, I mean a simple rock of a yellowish colour, harder than indurated claystone, and fusible into a black enamel before the blow-pipe. The breccia is in some cases very hard and compact, containing distinct fragments of trap in a paste of wacke. Other portions of the breccia were so fine that the component parts cannot be recognized. The most remarkable circumstance is, that the breccia has concreted into large spheroidal masses, varying in size from one to two feet in diameter. The spheroids are not so regular in their form as those of columnar trap, nor is it certain that they are composed of concentric crusts. The crusts in this instance appear to be the result of decomposition; for we find that they have assumed a red complexion, from the oxidation of the iron which enters into their constitution, while the unexposed central portions are of a bluish colour.

The next example we shall adduce is taken from Lynfield, so remarkable for its fine columnar façade. The mineral characters of the trap of this locality, are not different from those observed in other situations, and therefore need not be insisted on. Neither need we do more than mention, that at a quarry near the chapel, about a quarter of a mile from the columnar façade, the limestone has suffered the same changes as in the example already given at Cahir Parry. The only circumstance to which we will refer is the position of the breccias and wacke which occurs near Lynfield. This wacke is situated at the western extremity of the columnar trap, and consists of a uniform brownish substance, which is destitute of all fragmentary portions, has a distinct schistose structure, and is arranged in nearly horizontal beds, varying in thickness from an inch to six or seven inches. The arrangement of these fissile beds is extremely regular, and is well illustrated by Mr. Weaver's apt comparison to a pile of boards. A little higher up the hill, we find a second accumulation of similar materials; but in this instance, obviously possessed of a brecciated structure. A quarry which has been opened in this spot, developes in a very satisfactory manner the whole internal structure of the rock. The section thus afforded is about fifteen feet in depth; and although the breccia has a laminar structure, its stratification is very doubtful. It is divided into large cuboidal masses, which are made up numerous and parallel laminæ. But besides this lamination, the rock is also fissured at right angles to their plane: and hence the layers form long and narrow slips of about an inch in breadth, and a quarter of an inch in thickness, of an indefinite length. In some cases, the perpendicular fissures occur in two directions, and the laminæ split into beautiful rhomboidal plates of about two inches in breadth. The sides of these laminæ and rhomboidal plates are extremely smooth, and separated from the surrounding mass with the utmost precision. From these remarks, it appears that this mass is of mechanical origin, and cannot be confounded with any truly erupted rock; and also that its various concretionary forms are the result of causes which have operated subsequently to its deposition. We may, therefore, consider them as the result of the decomposition and attrition of the erupted rocks, washed down and deposited on their sides, and afterwards modified by a concretionary process.

Another instance of these erupted rocks is taken from Knockferna. This example is selected, because no doubt can exist of the insulation of this mass, as no other portion of trap occurs in the vicinity. The trap of Knockferna, and perhaps that of an adjoining hill, appears to be separated by a surrounding border of secondary strata from all the other trap masses of the district. Knockferna is the most elevated mass of trap in the country, forming one of the loftiest hills in the vicinity of Adare; and is further interesting, as it rises at the line of junction of the limestone with the subjacent sandstone. The mountain is crowned with, and surrounded by, a covering of trap breccia, which effectually conceals the other rocks. This rock is different from the other breccias, in being of a darker colour, and containing fewer fragments of any considerable size, and also approaches more to a schistose structure. Towards the summit of the hill it is in contact with the sandstone, and is there elevated into great tabular masses, resting on their edges. This tabular structure does not appear in the present case to depend on stratification; for although we find many of the beds accurately parallel to each other, still we find as many whose direction is at right angles to the former. This breccia is extremely ferrugenious; and contains fragments of trap, which attain to the size of a nut; and effervesces copiously when mixed with an acid.

It was a task of some difficulty to detect the presence of simple trap, which, no doubt, forms the nucleus of the mountain. I at last succeeded in finding it on the N. E. side, and about half-way up the ascent of the hill. In the vicinity of the trap we find the sandstone has been rendered more crystalline, approaching to the nature of quartz rock: the limestone is also rendered crystalline. It may be necessary to observe, that the trap is surrounded in three directions by the sandstone; and that it is only at its lower part and northern side, looking towards the Shannon, that it comes in contact with the limestone.

The examples which we have described will give some idea of the nature of the trap rocks of this district. It may now be added, that none occur on the north side of the Shannon, in the county of Clare; or perhaps it would be more accurate to say, that none have hitherto been detected. This caution will be vindicated by the following observation, from which it will be rendered probable that some indications of the proximity of trap have been detected on the Clare side of the Shannon. Near the village of Donass, on the north side of the river, and about five miles from Limerick, there are quarries of limestone, which are extensively wrought. The limestone is of the usual blue colour, and contains abundance of petrifactions of Terebratulæ, Productæ, Encrini, &c. The country is pretty level, but the limestone forms rounded elevations of but little height, and sections of some of them are displayed by the quarrying. In one of these situations the limestone becomes harder, and the fossils more firmly impacted in it; and in many parts only their outlines can be observed. At length all traces of fossils disappear—the limestone loses its blue colour, and becomes changed into granular crystalline marble, differing in no respect from the altered chalk found in contact with trap-dykes in the neighbourhood of Belfast. In this place no trap whatever is visible, nor could I procure any rolled fragments of it in the country around. Still we need not hesitate in ascribing the changes produced on the limestone to the influence of concealed trap, which has been unable to make its way to the surface. Trap occurs abundantly at a short distance on the other side of the river, and in some cases merely reaching the surface; so that we can do little more than detect its presence.

After this brief outline of the principal features of the trap district, it will be necessary to describe more fully the mineral characters of the different rocks of an igneous or other origin which have been observed in different localities. If I mistake not, the group of trap rocks may be arranged under two heads, characterised by essential differences of mineral composition and mode of origin. Under the first head will be included the simple erupted trap which has been protruded through the strata—whether in a solid or liquid state we need not yet inquire. The second class will comprehend the various breccias whose structure indicates a mechanical origin, and into whose composition comminuted trap largely enters.

Simple trap. The first division, therefore, includes the pure trap in the mineralogical sense of the word, and of course uncontaminated by the presence of any foreign or fragmentary matters. If the trap rocks of Limerick be so restricted, their mineral characters will be found to present but little variety. The first, by far the most common variety, consists of an intimate compound of felspar and augite, in which the component parts are so fine, that in general they cannot be distinguished by the eye. In some cases the crystals of augite become more apparent, so that their characters can be recognised. They are always small, and rarely above the length of a quarter of an inch. The presence of felspar is more doubtful: in no case could any distinct crystal of that substance be detected; so that, perhaps, the rock may be considered as a compact augite. The rock is extremely hard. Its fracture is between flat and conchoidal, and the fragments splintry. This is by far the most common variety, forming, with only two exceptions, the only simple trap which I have observed in Limerick.

The second variety occurs only at Knockferna; it is hard, has a splintry fracture, has no crystalline texture, and approaches very much in its appearance to altered clay schist or Lydian stone.

The third variety only occurs at Kilteely, where it assumes columnar forms of considerable regularity and beauty. This rock is a compact felspar of a beautiful flesh-red colour, and uniform appearance. Although very compact, it cannot be considered granular, but rather a very dense aggregation of extremely minute crystals of felspar. It frequently becomes porphyritic from the developement of small crystals of felspar, forming a felspar porphyry; as in the augite rock, the appearance of small crystals of that substance cause it to assume the character of an augite porphyry.

Such appears to be the only mineral varieties of trap which occur in the Limerick district, but these rocks also exhibit many varieties of concretionary structure. Although the trap is generally amorphous, and seldom exhibits any tendency to a laminar structure, still in many places it has assumed regular forms, as the columnar, polygonal, and orbicular. Examples of these varieties are far from rare. Columnar trap may be seen near the church of Cahir Parry; and a fine façade, first noticed by Mr. Weaver, occurs at Lynfield. The prisms are about eighty feet in length, and distinctly articulated, and ultimately resolvable into spheroidal masses. In this case the columns consist of augite rock. Another specimen of columnar trap occurs at Kilteely. The columns are about thirty feet in height, and consist of compact felspar, as formerly mentioned. It is unnecessary to enter into any farther details concerning these columnar rocks, as they have already been carefully described—the first by Mr. Weaver, and the second by Dr. Apjohn.

Another instance of the columnar form occurs in the village of Herbertstown, and was first pointed out to me by my excellent friend Captain Sabine. The village of Herbertstown is built upon the summit of basaltic columns; but as there is no natural section, the presence of the prisms is only visible in a space near the centre of the village, which was formerly opened as a quarry. This excavation has since been filled up; so that only a small portion of the rock is visible. The forms of the trap appear to have been extremely regular, forming cuboidal masses, which decompose into spheroids composed of successive crusts. In one of those masses, whose diameter is about three feet, a portion has been broken off one of the angles, and the successive laminæ, in this case, certainly not the result of weathering, are perspicuously displayed.

Breccias.—The second class into which we divided the trap rocks is of a more ambiguous nature. The rocks reserved for this division are all of a fragmentary nature, composed chiefly of fragments of trap and limestone, and in many cases united by a calcareous cement.

The first and simplest variety may be distinguished by the term wacke, which appears to be synonymous with the aphanite of Brongniart. It is of an earthy aspect, and a yellowish brown colour, resembling indurated clay, and easily scratched by the knife. At the base of the hill near Lynfield, it is very fine-grained, and is remarkable for the extreme regularity of its laminar structure. In this situation it is unmixed with any fragmentary substance. Near Cahir Parry it occurs in small seams, dispersed throughout the trap breccia. It is extremely fusible before the blow-pipe, melting into a black enamel, and does not effervesce with acids.

The second variety is of a coarser appearance than the preceding, and is obviously composed of minute fragments, included in a paste of the previously described variety. This variety occurs at Cahir Perry and other places; but no where with more distinctness than near Lynfield. There it forms a pretty extensive mass, which has already been described. The spheroidal concretions of Cahir Parry, as well as the rhomboidal and laminar concretions of Lynfield, occur in this variety.

The third variety possesses the brecciated structure in a still more decided manner; it also may be considered as the commonest of all, as it is found in Cahir Parry, Newtown, Carrig O'Gunnel, and Loch Gurr. The breccia of Carrig O'Gunnel is well seen on the low hills near the castle, where an interesting series of specimens may be readily selected. The most common kinds are of a soft texture, and extremely complicated nature, consisting of fragments of trap, semicrystalline limestone, and organic remains, imbedded in a green paste, and the whole held together by a calcareous cement. The fragments of trap are the least apparent, probably because their colour approaches to that of the including paste. The fragments of limestone vary from the smallest size to that of the fist; their edges are rounded; but their irregular forms prove that they have not been transported from any distance. The colour of the limestone is white, and its aspect compact and crystalline: its origin is revealed by the organic remains it includes, which are those of the carboniferous limestone. Its structure indicates that it has been altered by heat; while the included organic remains prove that the temperature has not been able to produce the fluidity of the stone. Besides the organic remains which occur in the breccia included in the calcareous fragments, stems of Encrini, not included in limestone, are disseminated through the mass in great profusion.

The fourth substance which enters into the composition of these breccias is the paste: this is of a green colour, resembling very much the green serpentine of New Jersey. It is scratched by the knife, and has an earthy aspect; and I am inclined to think that, in the case of the breccias of Corrig O'Gunnel, it is a true serpentine. Its green colour, however does not depend on the presence of chrome.

The last ingredient is the calcareous cement. Reflecting on the frequency of dolomitic limestones in the vicinity of pyroxenic rocks, it seemed probable that, in this instance, the calcareous cement might contain magnesia. On digesting a quantity of the breccia in muriatic acid, only a small portion was dissolved. On examining the solution, it was found to contain lime, iron, and magnesia: and hence the breccia is cemented by dolomitic matter.

At Carrig O'Gunnel, this breccia passes into a hard variolitic stone, whose nature could never be recognised from a hard specimen. This variety is very hard, and no traces of organic remains or fragments are any longer visible; their traces are merely indicated by the coloured blotches which a portion of the rock exhibits. These two varieties, although distinct at their extremes, graduate into each other; so that no line of separation can be drawn.

Between these extremes there is another variety, which occurs at Newtown, and affords beautiful specimens. In the present case, we have a hard stone breaking with an extremely flat fracture. In this fine breccia we observe distinct angular fragments of trap interspersed with fragments of a green colour, which appear to be serpentine, and numerous portions of calcareous spar scattered through the mass, but no recognisable pieces of limestone.

The fourth variety of this breccia may be denominated the amygdaloidal, and, at first sight, may be easily mistaken for a true amygdaloid. It differs, however, from the true amygdaloids, whose cavities have been filled by infiltration. The base of this amygdaloid is a compact earthy basalt. The only substance which fills the cavities is calcareous spar; and in no instance whatever could I detect any zeolite or chalcedony. The form of the cavities also differs from that which is produced by the expansion of an elastic vapour in a viscid liquid. Some of the cavities are bounded by plane surfaces; and their outline, instead of being rounded, is occasionally angular. The pseudo-amygdaloids have not been produced by infiltration; for, in some cases, we observe that the limestone nodule still retains the impression of a Terebratula, &c.; and some of the cavities in the rock are long and cylindrical, representing moulds of Encrinites.

The last variety which we shall mention, may be called the porphyritic. In this variety, which is very common, we have, as in the preceding, merely a modified trap breccia. The porphyritic structure is, in general, imperfect; but crystals of felspar are sufficiently common in the paste. All the porphyries which I have observed in the Limerick district may be arranged under this variety, and none of them belong to the class of erupted rocks. The felspar porphyry of Kilteely is, of course, an exception. The fragmentary nature of the base of these porphyries proves its mechanical origin; while the developement of the disseminated crystals requires the aid of some degree of heat.

After this outline of the principal features of the Limerick trap district, we may be permitted to add a few theoretical considerations as to their nature and mode of origin, and to contrast them with the erupted rocks of the north of Ireland; with which, while they have some analogy, they exhibit also some remarkable points of contrast.

In the Limerick district, the first circumstance which strikes us is, the absence of all veins of trap, and of all overflowing masses. It is true, this is only a negative proposition, and may, therefore, possibly be controverted; but if, after a patient investigation, conducted with as much care as the surface of the country would permit, and directed to this particular enquiry, no vein could be detected; and, farther, if the phenomena do not require their presence, the fact may be admitted till farther light be thrown upon the subject. As to the presence of overflowing masses, or, in other words, to the instance of alternations of trap and stratified rocks, the same negative answer may be given. The Limerick district has been alluded to by Mr. Weaver as affording examples of interstratification of trap and limestone; but the evidence which this accurate and patient observer brings forward, does not appear to be conclusive. The only conclusive evidence would be, to find a mass of trap beneath the limestone, while the latter was covered by another mass of trap. In this case, the proof, not of unstratified trap, but of the presence of overflowing trap, would be complete and decisive. No such instance could be observed.

There is, however, a fallacious appearance of alternations of trap and limestone, which admits of an adequate solution. As the trap has burst through the strata, it is obvious that the limestone must abut against it; and such is actually the case: and this limestone is also covered, not by overflowing trap, but by some one or other of the brecciated matters previously described. Of this we have many examples, as at Cahir Perry, where the outlaying trap is unquestionably a breccia; and also at Newtownhill and Corrig O'Gunnel. It is admitted that these overlaying beds often contain portions of rock differing very little from a genuine erupted rock; but a careful examination of numerous specimens will convince us that these portions always graduate into the brecciated substances.

From these details, we conclude that the trap of Limerick is of igneous origin, but that the different detached masses have been elevated after they had acquired some solidity: and hence the absence of veins and beds—which forms a remarkable contrast between the phenomena which the trap has produced in this district, compared with what we observe in Antrim. In Antrim, the chemical changes produced by the contiguity of the trap are much more extensive, as might be anticipated from its greater fluidity and consequent higher temperature; the chalk of Antrim has been changed into a white indurated limestone. In Limerick, on the other hand, it is only within a very short distance of the trap that the limestone is rendered crystalline, and it speedily resumes its ordinary appearance. If the chemical changes thus produced in the Limerick district are of small extent, it is not so with its mechanical effects. The disturbances, when we have access to them, are sufficiently striking. In those cases where the trap attains but little elevation, and the country is covered by vegetation, our means of observation are imperfect; but wherever sections are displayed by quarries, we find the limestone is no longer horizontal, but inclined at various angles, which become smaller as we recede from the trap. In those places where the country is uneven, as in the vicinity of Lough

Gurr, we find the limestone has been elevated to a considerable height, exhibiting numerous undulations; and dipping repeatedly in opposite directions, and forming abrupt precipices. The same remarks apply to the vicinity of Knockferna, where the disturbances have involved both the limestone and subjacent sandstone.

Besides these effects, which are sufficiently common elsewhere, we have extremely satisfactory evidences of mechanical violence in the abundance of brecciated rocks which every where surround the trap masses. As these breccias consist of trap and limestone, it is apparent that the latter has been shattered by the protruding rock. That these breccias have not been composed of debritus brought from a distance, can easily be established. None of the fragments bear the marks of prolonged attrition: on the contrary, they are often angular, as if they had been included in a paste immediately after their fracture. A still more decided proof is afforded by the constant and invariable absence of all other rocks: and I did not, in a single instance, detect one fragment of sandstone or quartz rock, although sandstone and conglomerates abound at no great distance. That these breccias should exhibit a great diversity of character, is not surprising: in some cases they appear to consist of fine trap sand alone; in others, fragments of trap and limestone are sufficiently obvious. Also the changes to which they have subsequently been exposed, have differed in different places. Some, as at Lynfield, have assumed laminar concretionary forms, others have become globular; some have been exposed to heat, as is proved by their porphyritic structure; and in some cases this agent has obliterated all traces of brecciated structure, leaving, however, traces of it in the blotches which variegate the rock.

In concluding, I may remark, that the theory of unstratified rocks having been elevated in masses after solidification, is no new idea, and is necessary for the solution of many geological phenomena. That stratified rocks have been upheaved from beneath the ocean, is admitted by all; and we have no reason to refuse the same elevation to some granites, traps, and porphyries. I may also add, that the same theory which I have applied to the trap rocks of Limerick, has been already employed by Messrs. Murchison and Sedgwick in explaining the elevation of the granite rocks of Arran and Caithness; and that the granitic conglomerate observed by these gentlemen at the base of the Ord of Caithness, has considerable analogy with the breccias described in this paper.

REMARKS ON THE NATURAL HISTORY OF THE FOSSIL ELK.

BY JOHN SCOULER, M. D. F. L. S. &c.

(Read Nov. 9th, 1836.)

The researches of Cuvier, and the valuable observations ot Dr. Hart, respecting the fossil elk, have completely exhausted all that can be said concerning its osteology, and fully established its claim to be considered as a distinct and extremely well characterised species. With the data thus obtained as a basis for further inquiry, many interesting questions arise, which are still far from being solved in a satisfactory manner. We have yet to investigate more fully the causes which have led to its extinction; what were its habits compared with those of the modern elk; whether the latest individuals of the species had ceased to exist before the countries which it inhabited began to be occupied by the human race.

The first question we shall consider is, Whether the latest individuals of the Cervus megaceros were contemporary with the earliest human settlers which occupied the western parts of Europe?

The evidence which we possess on this interesting question is of two kinds—historical traditions, and the geological circumstances under which the remains of the elk occur. Dr. Hibbert in particular attaches much importance to the historical evidence, which, he thinks, establishes the fact that the Cervus megaceros was known to the Romans, that it was exhibited at their Circensian games, and that the race did not finally disappear till so late as the year 1550, if indeed it be yet totally extinct.* Speaking of the causes which have tended to the extinction of the fossil elk, he has the following remark: "A second cause contributing to the extinction of the Cervus Euryceros, was the estimation in which all the remarkable animals inhabiting Gaul, as well as the other regions, were held by the Romans for the use of the public games." The evidences on which this learned and ingenious writer relies for the establishing of this position, are drawn from the works of Julius Capitolinus, and the poem by Oppian upon hunting. Before investigating the value of this testimony, it may be proper to remark, that the different species of Cervus are so vaguely characterised by the writers of antiquity, that it is in many instances extremely difficult to ascertain the species whose names occur in their works, and also that different species are not unfrequently designated by the same appellation. The common elk was certainly known to the ancients. It is mentioned, though very vaguely, by Cesar, as an inhabitant of the Hercynian forest. Pausanias also names it as a wild animal inhabiting the country of the Celts—that is, the northern parts of Europe. The words of Pliny are, however, more to the purpose; he says, it is a native of Sweden, but adds, that down to his own time it had never been seen at Rome. We may, therefore, conclude, that no elk had been exhibited at the Roman games before the time of the Antonines. At a later period the animal became better known; for Julius Capitolinus informs us, that elks were shown by Gordian; and Vopiscus mentions, that Aurelian exhibited the rare spectacle of the elk, the tiger, and the giraffe, when he triumphed over Zenobia.

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* Hibbert Ed. Journ. of Science, vol. 3d. 1825, p. 15, and p. 129. See also the same Journal, New Series, 1830, vol. 2d, p. 306.

We have now to ascertain whether a second species of elk, the Cervus megaceros, was known to the Romans, as is the opinion of Dr. Hibbert. This opinion he endeavours to support on the strength of two passages—the one taken from Oppian's poem on hunting, and the other, which is much less conclusive, from Julius Capitolinus. We shall first allude to the passage from Oppian, which is the more important one. The Euryceros, which is supposed to be the same as the fossil elk, is distinguished, according to Oppian, by the following characters.* It is of the tribe of deers, but excels them all in the greatness of its horns; it is larger than the bubulus, which again is larger than the dorcas. By the dorcas the ancients meant either the roebuck or the gazelle; and the bubulus in this passage is obviously not the buffalo, but the Antelope bubulus, an animal rather larger than the fallow deer. We have here, therefore, a deer with wide spreading horns, and of greater size than the ordinary kinds. But there is no necessity for considering it as identical with the fossil elk; it is in all probability the common elk of the north of Europe. Oppian, who viewed animals with the eye of a naturalist, and has left many valuable indications to guide us to the meaning of contemporary authors, was not ignorant of the animals of the north of Europe, as is evident from his history of the bison only a few passages farther back in the same book.

The next quotation is still more unsatisfactory than the preceding one. Agreeing in opinion with Aldrovandus, Dr. Hibbert suspects that the palmated stag mentioned by J. Capitolinus may refer to a larger species than the fallow deer, and different from the common elk. "That many of these cervi came from Britain," says Dr. H. "is evident by the remark of Capitolinus regarding a picture of the memorable wood of Gordian, which existed in the house of Pompey." Gordiani Sylva memorabilis picta in domo vostrata Cu. Pompeii picturas animalium diversas continet, inter quas sunt *cervi palmati* ducenti mixtis Britannis. The meaning of this passage is abundantly obscure; the epithet *cervi palmati* may apply to the fossil elk, the modern species, the rein deer, or the fallow deer But to suppose the epithet to apply to any of the three first species in the sentence above quoted appears extravagant, especially when we are informed by the same author, that Gordian only exhibited ten elks. We should be inclined to suppose, that the *cervi palmati* alluded to by Capitolinus were fallow deer, especially as Pliny, in speaking of the platyceros, or fallow deer, applies to it the same designation. Animalia quorundam cornua in palmas finxit natura, digitosque emisit ex eis unde platycerotas vocant. We may, therefore, render the *cervi palmati ducenti*, by two hundred fallow deer. But what was the British species mixed with them? It is difficult to say; but as England possesses two varieties of the fallow deer, the brown and the spotted, perhaps it was the former.*

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* Oppian Cyneget. B. v. 293 and 300.

When we reflect on the avidity with which the Romans collected wild and rare animals, and that such were ever considered most acceptable presents by the emperors, as ornaments of their triumphs, or contributing to the splendour of their games, we need not be surprised that almost all the larger quadrupeds of Africa and Asia were well known to the writers who flourished under the empire. Had the fossil elk existed during the three first centuries, it would scarcely have escaped the observation of a people who knew the two-horned rhinoceros and the zebra, and who often saw the Bengal tiger. We may safely conclude from the words of Pliny, that no elk had been seen at Rome before his time, and long before that period Britain had been reduced to a province, and consequently the knowledge of Ireland must have been greater than at any preceding period. The Roman authors, especially the cynegetic poets, have given descriptions of the different British dogs; the Scotch terrier is accurately described by Oppian ; and Irish wolf dogs were brought to Rome about the fourth century. How then did the Irish elk escape all notice if it was then in existence ? The descriptions of the alces, although very imperfect, and mixed with fables, can only belong to the Scandinavian species. The fictions related by Cesar and Pliny respecting the liability of the elk to fits of epilepsy, that it had no joints to its fore-legs, and was in consequence obliged to sleep in a standing position, resting against a tree, have all reference to the disproportionate length of its anterior extremities—a character which remarkably distinguishes the modern species from the fossil one. Pliny has left another indication which prevents all mistake—namely, the length of the snout. Labrum ei superius prægrande ob id retrograditur in pascendo nec in priora tendens involvatur. This trait is inapplicable to any known species of deer, either living or fossil, except the modern elk. We may, therefore, conclude, that if so remarkable an animal as the fossil elk had been known to the Romans, some more decisive evidence of the fact would have remained.

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* Cuvier, in his Recherches sur les Ossemens Fossiles, t. 4, p. 31, states that we have no positive information as to the native country of the fallow deer. It appears to have been introduced at a very modern period into the different kingdoms of the north of Europe; and Pennant thinks that the spotted variety was introduced into England from India, and that the brown race was brought from Norway by James I. In the Regne Animal, 2d edit. vol. 1, p. 262, he says, it is probably a native of Barbary, and that he has received the skin of a wild individual which was killed in the forests to the south of Tunis. But as Mr. Philips, in his Illustrations of the Geology of Yorkshire, mentions that the horns of the fallow deer have been found along with those of the Cervus megaceros, consequently the fallow deer is indigenous to England, and probably the species alluded to by Capitolinus.

The modern authority, and the one which is chiefly relied on, if valid, would establish the important fact, that the Cervus megaceros was an inhabitant of Prussia so late as the year 1559. Sebastian Munster is the authority cited by Dr. Hibbert ; but I think his evidence is scarcely more convincing than that of Oppian or J. Capitolinus. In his account of the animals of Prussia he is obviously much perplexed respecting the history of the elk, of which it must be admitted he suspects the existence of more than one species. He also gives a figure, accompanied by a description, of an animal which, as it differs considerably from the figure of the common elk, is supposed to represent the extinct Irish species. If we attend to the description alone, we will find that there is nothing in it which does not refer to the common species. What he says of the extreme strength of its skin, its size being that of a moderately large horse, and the use of its hoof in the cure of epilepsy, obviously apply to the common elk. If the description is thus unsatisfactory, the figure is still more so; for if we examine it minutely, we perceive that it has little resemblance to any known species. The horns are obviously different from those of the common elk ; but they differ as much from those of the extinct species. As Munster says that his animal was depicted to the life, it becomes interesting to ascertain what species he might have in view. On consulting Gesner, I think I have discovered that the animal intended was not the fossil elk, but the fallow deer. If we inspect the figure given by Gesner* of the fallow deer, we perceive that it bears a striking resemblance to Munster's figure—the animal is represented in very nearly a similar position, and if we omit the consideration of the horns, the bodies of the two animals differ in almost no respect. In Gesner's figure the horns have two brow antlers, but in Munster's they have only one; in other respects the horns of the last mentioned figure do not, in my opinion, admit of rigid comparison with any species. If to these remarks it be added, that Munster was the friend and correspondent of Gesner, we may infer from the silence of that sagacious writer respecting the opinions of Munster, that they did not appear to him to be conclusive. We ought also to mention, that, at that period, the writers on natural history were, far more than at present, perplexed with nominal species, produced from their desire to bring their own observations into accordance with the indistinct traditions handed down from antiquity by the classic authors. Whoever has examined the works of the writers of the fifteenth century, will find them to abound with nominal species. Thus the rein deer has been considered as two distinct species, the rangifer and tarandus; and Aldrovandus, misled by a passage in Pliny, and the remarks of his predecessors, attempted to establish a second species of elk, under the name of *magna animal;* although, in this case, the acuteness of Gesner had already suspected the source of error.

What now remains to be considered in the historical part of the question may be briefly passed over. When we recollect the abundance of horns of the fossil elk, which occur every where throughout Ireland, and which appear to have attracted observation before the time of Molyneux, it is remarkable that no notice of them should have occurred either in the different writers from Giraldus down to Boates, and still more so that no account of them should be found in any of the indigenous Irish chroniclers and poets. We might have expected that, even although the race had become extinct, the poets would have availed themselves of the traditions concerning it as an embellishment to their works, as the Siberians and Chinese have their fables respecting the extinct elephant.

The ingenious and learned historian of Manchester is of opinion that the moose deer, as he calls it, was in existence while the Romans occupied England, and even that the race of dogs by which it was hunted still survive. He is further of opinion, that it was the *segh* of the ancient Britons, and inhabited the woods around Manchester, till finally extirpated by the progress of civilization.*

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* De Quadrupedibus, p. 1100, ed. 1551.

Goldfuss is of opinion that the elk was known to the ancient Germans, and quotes a passage from the Niebelungen, a poem whose antiquity cannot be dated later than the thirteenth century, to prove, not that the animal was then in existence, but that traditions concerning it still survived. It was denominated a schelch, which the hero Sifred is made to slay along with several of the larger herbivoræ.

> Dar nach schlach ein schiere einen wisent und einen elch
> Starcher ure viere und einen grimmen schelch.

In this couplet the larger herbivorous quadrupeds of Germany are all enumerated—the bison, the elk, and the urus; but from the epithet applied to the schelch, may it not rather indicate a carnivorous animal?

If the historical evidence be so unsatisfactory, our only resource is to examine the geological relations of the animal, where the indications are, at least in this case, less obscure. That the fossil elk was the contemporary of the elephant on the one hand, and of our existing races on the other, admits of but little doubt. The bones of the fossil elk have been found along with the remains of the elephant in the forest of Bondi, near Paris; and it is extremely probable that these two great animals lived together in Ireland. In the only authentic instance in which the remains of the elephant have been found in this country, they occurred in a position indicative of as modern a date as that in which the remains of the elk have also been noticed. These remains of the elephant were found reposing on a bed of ferns and rushes, proving that the vegetation of the country was the same then as now. On the coast of Yorkshire the remains of the elk have been found in a submarine peat, containing trees with nuts, with the bones of oxen, and with the bones of the red and fallow deer.† The bones of the fine skeleton preserved in the Museum of the Dublin Society, were found associated with the bones of some carnivorous animal, probably a dog. It is remarkable that hitherto no indications of the presence of the bones of other ruminating quadrupeds in the marl of Ireland have been recorded. The bones of the extinct race of oxen, the horns of the red deer, which are found in multitudes in the lakes of Forfarshire, associated with the skulls of wolves, and even of beavers, do not occur in Ireland, or have escaped notice.

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* Llhuyd in Archiologia Britannica in his Welsh Vocabulary gives the following definitions of Segh, an ox, a buffalo, bison, &c. Quere—whether a kind of the moose?

† Phillip's Geology of Yorkshire.

But the most interesting question remains to be considered —was the fossil elk contemporary with man? If absolute certainty has not yet been obtained on this point, there are at least several circumstances which would render such a supposition extremely probable. The only evidence on this head not liable to cavil, would consist in finding the remains of works of human art or human bones either under or in the same bed as those of the fossil elk. A considerable number of such instances will be quoted, but, unfortunately, they are all so denuded of circumstantial details, that the question cannot be considered as definitely settled.

The first instance in which remains of human art are said to have been found along with the remains of the fossil elk, is one given by Pownall; but, unfortunately, the notice is only incidental in a paper relating to a different subject. In giving an account of the ancient ornaments found in the bog of Callen, in Tipperary, he states the following circumstances:—In digging away the bog about six feet deep as far as it extended, there was nothing found only trunks of different trees, all rotten, except the oak and fir, which were for the most part sound, and some horns, large enough to have a circle of about three feet in diameter described on each palm. He then describes a great number of gold and other ornaments which had been found at different periods in the same bog. I think the fair interpretation of this sentence would indicate that the horns were found not in marl but in peat, and in this case the quotation might be considered as decisive. Unfortunately, the writer appears to have been careless about the subject, and consequently, through inadvertence, might commit some mistake as to the position in which the horns occurred.

Leigh, in his History of Lancashire, has some statements which have been alluded to by Dr. Hibbert; but they are still more vague than in the preceding case. He gives several instances in which the horns of the fossil elk had been found in Lancashire, in bogs; and also that the head of a hippopotamus had been found in the same position. In another place he

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[*] Pownal Archæolog. Britain. vol. 3, p. 359.

states, that eight canoes were found imbedden in marl, on draining the Marton meer in Lancashire. In this instance, it is true that the horns and canoes were found in different but not very remote situations: and assuming that the canoes were actually imbedded in the marl (which appears highly probable) we may conclude that they were of an equal antiquity with those of the elk. If so, we shall next be compelled to admit that the hippopotamus was also the companion of the ancient Celtic tribes of England.

Professor Goldfus, in this account of the horns of the elk found in the Duchy of Cleves, remarks, that they were found at but a small distance from the surface; and that urns and stone hatchets were found in the same place. He, however, does not say whether the urns and hatchets were found *above* the remains of the elk, or at the *same level* in the *same bed.**

Such appears to be the amount of evidence on this very interesting question. Nothing decisive can, in my opinion, be deduced from the historical testimonies. Their indications may all be referred to existing species of the deer tribe: it is different with the geological evidence; for although each individual proof may be explained away, still the different instances, when considered more generally, appear to favour the idea that the fossil elk was the contemporary of man, still it would be extremely hazardous to infer that the efforts of the savage hunter was one of the causes which led to the destruction of the elk, till some more decisive facts be brought to bear on the question.

The only remaining evidence is that brought forward by Dr. Hart, and is of a different nature from the preceding cases. He describes a rib, in which there is an oval opening, as if the result of a wound produced by some sharp cutting instrument. This, however, is not conclusive as to the question; for the wound might have been occasioned by other causes than the arrow of a primeval hunter. The combats of two males might cause the wound: and it is deserving of notice, that, in the very locality where the rib was found, two heads were found with the antlers entwined in each other. The teeth of a carnivorous animal might also have caused the wound; and, finally, the wound from the branch of a tree, while the animal was swimming, might also cause the mark of violence which we perceive on the rib.

The occurrence of the remains of the elk in mere superficial peat above the marl, is another argument, and one which has a high degree of probability attached to it. Several of the remains found by Archdeacon Maunsell were in the superficial peat. Mr. Weaver * repeats the same circumstance. Its bones and horns, he says, occur in the bog of Kilmegan, near Dundrum, in the county of Down. They lie at the bottom of the peat, between it and a bed of shell marl; resting on or being merely impressed in the marl, which is composed of a bed of fresh-water shells, from one to five feet thick, and must have been formed, when the bog was a shallow lake.

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* Cuvier Ossemens fossiles.

If we compare the geographical limits which bound the range of the fossil and recent elk, we will find, as Dr. Hibbert was the first to remark, that their respective provinces have been assigned to them with no less precision than their specific characters. The modern elk is an inhabitant of the northern parts of the old and new worlds. In Europe, his native country is the Scandinavian peninsula, as Pliny long ago remarked; from thence its range extends to the north of Prussia, and eastward to the woody parts of Siberia, as far as the Uralian mountains. It does not appear that the common elk was ever an inhabitant of France, England, or Ireland, nor, in short, of any of those countries inhabited by the extinct species: and, on the contrary, no remains of the extinct race have been hitherto found in the native districts of the existing species.

If the Scandinavian peninsula was the native country of the common elk, Ireland was the aboriginal residence of the fossil species, whose range extended to the line which bounds the domain of the Swedish elk. The remains of the fossil elk become rarer as we recede from Ireland, and advance to the east or north. Next to Ireland, it appears to have been most numerous in the Isle of Man. No specimens have hitherto been found in Scotland; but if, from the Isle of Man, we pass to the adjoining district of Lancashire, we find that its remains are more abundant there than in any other part of England. It is less abundant in France than in England; but it extended into Germany and along the Rhine, till it finally disappears where the country of the modern species begins. On the south, it spreads as far as the plains of Lombardy. No remains of this animal have been found in North America; nor am I aware of any instance in which the remains of the modern elk have been found in peat or marl in the countries where the fossil species lived.

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* Hart, Description of the Fossil Deer, p. 29. Weaver, Ed. Phil. Journ. 1825, vol. xii. p. 319.

Were the habits of the fossil elk different from those of the existing species?

Within certain limits, the organization of any animal being known, we can form a tolerably correct opinion respecting its habits or relations to other objects. We can ascertain whether it was carnivorous or herbivorous, and even to which of the subordinate sections of these great classes it belonged; and also we can form a correct notion of the medium in which it moved: but, beyond this, another cause comes into action, which escapes the rules of the anatomist. We cannot, from the structure of an animal, infer its peculiar instincts, any more than the colour of its integuments. No osteological indications would induce us to believe that the habits of nearly allied species should differ so remarkably. In the deer tribe, nothing but actual observation would convince us that the greatest animals of the genus are inhabitants of cold or temperate countries; or that while most of the species feed on the young branches of trees, or frequent marshy places, one species should derive its support from a lichen.

The two species of elk are, however, those which present the most remarkable differences: and hence we may infer a considerable difference in their habits. The modern elk appears to be the most awkwardly constructed of the genus. Its neck is short, to support its unwieldy horns (which often weigh fifty pounds); but, by a strange anomaly, its anterior extremities are disproportionately high: so that it would appear, at first sight, that the animal would have great difficulty in obtaining its food. These important peculiarities could not exist with involving others which correspond with them. The head of the common elk differs from that of all the other species of cervus: the nasal bones are extremely short, and do not reach to the intermaxillaries; thus affording space for a thick and powerful snout, intermediate, as M. Bory St. Vincent observes, between that of the horse and tapir. Four muscles arise from the maxillaries, and give vigour to this snout. Hence the elk is not properly a grazing animal, but feeds on the long grass and reeds on the margins of lakes, and the young branches of willows along the banks of rivers. The account of their habits given by Hearne, is an excellent commentary on this account of their organization:—" Their legs are so long, and their necks so short, that they cannot graze on the level ground, like other animals, but are obliged to browse on the tops of large plants and the leaves of trees in the summer; and, in winter, they feed on the tops of willows and the small branches of the birch tree: on which account, they are never found during that season but in such places as can afford them a plentiful supply of their favourite food; and although they have no fore teeth in the upper jaw, yet I have often seen willows and small birch trees cropped by them in the same manner as if they had been cut by a gardener's sheers, though some of them were as thick as the finger." The modern elk is, therefore, an animal inhabiting marshy places, where long grass and shrubby plants abound, the size of his horns preventing them from frequenting the recesses of forests, and the length of their limbs and short neck hindering them from grazing on the plains.

If we now examine the fossil elk, we find that its structure and appearance were very different from those of its modern congener. The length of its extremities are as well proportioned to its body as in the rest of the deer tribe; and its graceful outline contrasts it favourably with the modern species. As its limbs were well proportioned, so the relations of its nasal bones do not divaricate from the common type of the Cervi. Under these circumstances, without the advantage of a short neck to support its stately antlers, the muscles of the head must have been prodigiously developed: and hence we may infer that the processes of the first dorsal vertebræ must have been much stronger in proportion than in the common elk. "The size of the cervical vertebræ," says Dr. Hart, "greatly exceeds that of the other classes, and the spines of the dorsal were a foot in height. The necessity of these bones being so marked is obvious, considering the strong cervical ligament and powerful muscles supporting and moving a head which, at a moderate calculation, must have sustained three quarters of a hundred of solid bony matter." These considerations are further illustrated by an examination of the respective lengths of the head in the two species. The average length of the head in the two species is nearly equal (about two feet); or, in other words, that of the common elk is the longer, in compensation for the brevity of its neck, and is thus in harmony with the rest of its structure. The long neck of the extinct species did not require such a length of cranium. It may also be remarked, that the infra orbitary aperture is smaller in the extinct species; while the great snout of the common species required a proportionately larger supply of nerves.

From these data, we may infer that the habits of the fossil elk differed in some details from those of the northern species. Both were excluded from the regions of dense forests; but the extinct species was, perhaps, less servilely bound to reside on the banks of lakes and rivers, and probably pastured on the rich meadows as well as in the marshes; but, like most of the deer tribe, preferred the young branches of trees. It can scarcely be doubted that it was gregarious: the number of horns so often found in the same spot, appear to establish this analogy between its habits and those of the other species.

What were the causes which led to the extinction of the fossil elk?

This is a question extremely difficult to solve; and I do not know that any satisfactory hypothesis has yet been proposed. If the Swedish elk still survives, in spite of having had to contend with man for so many centuries, how does it happen that the Irish species disappeared so early? Ireland appears to have been a country peculiarly adapted for the preservation of the race: a favourable climate, affording abundance of food at all times of the year, its mild winters always affording some verdure; while Sweden, the country of the surviving species, is, for nearly six months in the year, locked up in frost. Again, Ireland appears to have been remarkably free from the larger carnivoræ: the only species which we have historic testimony that it ever possessed, are the wolf and the wolf-dog; of the fossil species it does not appear ever to have possessed any. Although caverns and fissures are sufficiently abundant in all the limestone country, no fossil hyæna, bear, or tiger has ever yet been discovered; nor have any such remains been ever found in the gravel, clay, or marl beds throughout the country: and, till some such remains be found in Ireland, we are not entitled to assume that the ravages of the extinct carnivoræ was a cause which thinned the numbers of the fossil elk.

Perhaps our knowledge of the habits of the fossil elk, scanty as it is, may be of use in this enquiry. It is obvious that the fossil elk was not destitute of the means of protection. Like the existing species, it was probably a suspicious animal: but, on this head, it is unsafe to speculate, as much diversity prevails among the deer tribe in this respect; the wapiti, for instance, is said to be the "most stupid of its tribe." A better ascertained mode of defence might consist in its powerful and massy antlers, which would act as a broad shield, protecting it against attack, and enabling it, by a side blow, to deal deadly wounds amongst its assailants. In addition to this means, the analogy of the northern species would lead us to suppose that its feet were a no less powerful resource. A correspondent of Gesner's, who resided in the north of Europe, informs us that the elk, with its fore feet, transfixes dogs and hunters as with a spear.*

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* "Anteriovibus pedibus canes et venatores tanquam cuspide trajecit. But," he adds, "vulnerum impatiens non illa tanta ad similitudinem magnitudinem

The following hypothesis may be suggested respecting the causes which led to the extinction of this noble animal. As depending on the gradual increase of forest and bog in the country, which, by narrowing the range of the elk to smaller districts, rendered it more easily the prey of wild animals. It is no mere hypothesis to assume that the surface of Ireland has, at a recent period, suffered many physical changes, brought about partly by natural causes, and in part by the progress of society. We can easily contemplate a period, and not a remote one, when the country abounded in shallow lakes, and the more elevated parts were covered by magnificent forests of the pine, the yew, and the oak; and even within a very recent historical epoch, a great part of the country was one immense forest, and great part of the remainder was one uniform surface of bog. The elk could not subsist in the dense forests, the asylum of its foes, and which its antlers prevented it from entering; the obliteration of the lakes, and the growth of peat in those situations where the drainage is imperfect, would, therefore, gradually narrow the domain of the fossil elk. But while thus diminishing his means of subsistence, it would also limit his means of escape from danger; while the chances of being immersed in the semifluid peat and marl would every day increase. In consequence of this, great numbers would get entangled in the bogs, and thus perish. " In the extensive bogs of Newfoundland," says Mr. Lyell, " cattle are sometimes found buried, with their heads only and neck above ground; and, after having remained for days in that situation, they have been drawn out by ropes, and saved." In Ireland, Mr. King asserts that the numbers of cattle which are lost in sloughs is quite incredible. The same author states, that several hundred skeletons of deer and other animals have been obtained, within the last century, from a few small marl lakes in Forfarshire. Hundreds of red deer have also perished, in this manner, in the peat of the valley of Loire, in France. The destruction of the elk, by this means, would not result merely from its own inattention, but whole herds, urged by their fears, would thus perish in attempting to escape from their pursuers. Still it is clear that the mere pursuit of the elk by beasts of prey could not alone cause its destruction: unless increase of forests and bogs had narrowed the means of obtaining food, and of escaping from danger, the Irish elk might long have stood its ground like the kindred species.

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duorum cervorum, uno vulnere prosternitur aut mediocri ictu bombardæ."—*Gesner, Hist. Quadruped.*

In conclusion, it may be observed, that no facts connected with the history of the fossil elk would induce us to suppose that any change has taken place in the climate of Ireland since the period when the elk first appeared upon it. It was contemporary with animals which live in the country at present, and was, of course, adapted to the same temperature as they are. The vegetation which afforded it food still exists, and the climate probably remains unchanged. If we were to speculate on changes of climate from the presence of the larger species of the deer tribe, the strange inference would be, that the climate was then colder than at present.

The total absence of all remains of extinct carnivoræ, and the great rarity of the bones of the fossil pachydermata in Ireland, is another remarkable circumstance connected with the history of the fossil elk. The conclusion is a negative one: but as only one example of the occurrence of the remains of the elephant is on record; and as no one has ever detected a fragment of a bone of the rhinoceros, mastodon, or hippopotamus; and as none of the numerous caves of Ireland have ever afforded a single tooth of a bear, a tiger, or a hyæna, we may conclude that such beasts are extremely rare. Thus the abundance of the fossil elk in former times may be, perhaps, in part accounted for by the absence or rarity of the great pachydermata, which might have disputed with them for the possession of feeding ground; and the absence of the carnivoræ, whose energies might have thinned its numbers.

ON THE OPTICAL PROPERTIES OF CRYSTALS, AND THEIR RELATION TO THE CRYSTALLINE FORMS.

(Being the substance of a Lecture delivered before the Society, on Wednesday, June 8.)

The discovery of a connecting link between remote classes of phenomena, is among the most grateful of the fruits of physical research, as it is also one of the most promising. Such a connexion is not only a real addition to our knowledge—and in its highest department, that of generalization—but it further holds out an almost certain clue to future and higher discovery. When physical laws, which appear to be insulated and independent, are unexpectedly found to have some points of contact, we not only learn that they have a common origin, but we are also furnished with the most direct intimation of its nature. Among the multitude of possible causes, to which either, separately, may be referred, there are few which can account for both; and the path of induction becomes narrow and certain.

These remarks appear to apply to the connexion which has, not long since, been traced between the optical properties of minerals and their primitive forms; and it is to this subject —a subject due, almost exclusively, to the skill and labour of one distinguished philosopher—that I beg to invite the attention of the Society. I shall begin by stating, briefly, a few of the leading circumstances of the action of crystals upon light.

When a ray of light falls upon the surface of a transparent medium—such as glass or water—which is devoid of all crystalline arrangement, it is divided into two portions: one of which is turned back, or *reflected*, at the boundary surface; while the other enters the medium in an altered direction, and is said to be *refracted*. The phenomenon is different, however, when the medium on which the ray falls is *crystallized*. In all such cases (with a few exceptions to be hereafter noticed), the portion which enters the medium is divided into *two distinct pencils*, and the light is said to undergo *double refraction*.

This property is the source of most of the optical phenomena of minerals. It was first noticed by Bartholinus, in Iceland spar; but though the account of his experiments was published some time before the close of the seventeenth century, the subject drew little attention; and no addition was made to the knowledge of its laws, until the close of the eighteenth, and the commencement of the present, century.

Carbonate of lime, of which Iceland spar is a variety, crystallizes in more than 300 different forms, which are all derived from the rhombohedron. The angles of the parallelogrammic faces of the primitive form are, very nearly, 102° and 78°. Two of the solid angles of the rhombohedron are contained by three of the obtuse angles, while the remaining four are bounded by one obtuse and two acute angles. The line joining the summits of the obtuse solid angles is called the *axis* of the rhombohedron, and is equally inclined to the three faces which compose the solid angles. The angles at which the faces themselves are mutually inclined, are 105° and 75°, nearly.

The phenomenon of double refraction may be simply observed, by laying a piece of this substance upon a sheet of white paper, on which a small black spot is marked with ink. On looking through the crystal, we shall see two images of the spot, instead of one; and if the eye be held perpendicularly above the surface, and the crystal turned round in its own plane, one of these images will describe a circle round the other, the line connecting them being always in the direction of the shorter diagonal of the rhombic face.

If we allow a ray of the sun's light to fall on the crystal, and examine attentively the *course* of the two refracted rays, it will be found that, at a perpendicular incidence, the deviation of one of them is *nothing;* and that, at any other incidence, it is bent towards the perpendicular, the angles of incidence and refraction being in the *same plane,* and their sines in a *constant ratio.* This ray, therefore, is refracted according to the known law, and is termed the *ordinary* ray. On examining the other ray, however, we find that at a perpendicular incidence the deviation, instead of vanishing, is more than 6°; that at other incidences the refracted ray does *not* follow the law of the sines; and that, moreover, the angles of incidence and refraction are, in general, in *different planes.* This ray, being bent or refracted according to a new law, is called the *extraordinary* ray.

It would be beside our present purpose to enter more minutely into the consideration of the *law* of double refraction. It is, however, necessary to observe, that there is a certain direction in every double-refracting crystal; along which, if a ray be transmitted, it is no longer divided, and there is no bifurcation of the pencil. This line is called the *optic axis,* and all the phenomena of double refraction are related to it. In truth, there is an infinite number of such lines in every crystal, but they are all parallel; so that the optic axis is fixed, not in absolute position, but in *direction* only. It has been already stated that the line connecting the obtuse solid angles of the regular rhombohedron of Iceland spar is called the *axis of the crystal.* Now, if we conceive any crystallized mass of this substance to be subdivided into elementary molecules of this form, the axis of each of these molecules will be an optic axis. The optic axis of the crystal, therefore, is a *direction* in space parallel to the axis of form of the elementary molecules; or equally inclined to the three faces containing the obtuse solid angle.

The properties of the crystal are symmetrical on all sides of the optic axis. When the direction of the ray within the crystal coincides with the optic axis, the ordinary and extraordinary rays coincide. Their separation increases with the inclination to the axis, being the same on all sides of it as long as the inclination is the same; and it is greatest when the ray is perpendicular to the axis.

In Iceland spar, the extraordinary ray is always more inclined to the axis than the ordinary ray, or it is refracted *from the axis*. This, however, is not the case in all double-refracting crystals. M. Biot discovered that there were many crystals in which the extraordinary ray is refracted *towards the axis*. Crystals of this kind he called *attractive;* while those in which the extraordinary ray is refracted *from* the axis, were denominated *repulsive*. Sir David Brewster has proposed to substitute for these terms the words *positive* and *negative*, as being unconnected with theoretical views. Among the positive, or attractive crystals, are *quartz*, *zircon*, &c. The repulsive or negative class is far more numerous, and includes, amongst others, *Iceland spar*, *sapphire*, *ruby*, *emerald*, *beryl*, and *tourmaline*.

We have hitherto assumed that in every crystal there is but *one* optic axis, or one direction along which a ray will pass without division. It was reserved for Sir David Brewster to discover that the greater number of crystals possessed *two optic axes*, and that there existed a connexion between these diversities of character and the varieties of crystalline form. Among the most remarkable of the crystals with two axes, may be mentioned *arragonite*, *mica*, *sulphate of barytes*, *sulphate of strontian*, *sulphate of lime*, *topaz*, *felspar*. The angles contained between the axes range in magnitude through the entire quadrant; and they accordingly afford a new and most important criterion for the distinction of mineral substances.

Having thus briefly enumerated some of the leading phenomena of double refraction, we may proceed to consider the relations which have been established between these various properties and the crystalline forms of the substances in which they are found to reside. These important relations were discovered by Sir David Brewster, and published in a memoir read before the Royal Society in the year 1818.

It will appear from the foregoing, that crystalline bodies may be divided into three grand classes with respect to their action on light:—

1. Single-refracting crystals.
2. Uniaxal crystals, or those which have one axis of double refraction.
3. Biaxal crystals, or those which have two such axes.

Now, Sir David Brewster has discovered that all the crystals of the first class, *i. e.* all *single-refracting crystals*, belong to the *tessular* system of Mohs;—that all *uniaxal* crystals belong either to the *rhombohedral* or *pyramidal* system; and that crystals of the third class, or *biaxal* crystals, belong to one or other of the *prismatic* systems.*

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* The prismatic, hemiprismatic, and tetartoprismatic.

These important laws were the result of long and patient induction; and, in the progress of this research, many seeming exceptions arose, which afterwards yielded to a closer examination, and confirmed the rule which they appeared at first to oppose. One of the most remarkable instances of this kind occurred in the *sulphato-tricarbonate of lead*, a mineral which had been placed by Count Bournon and Mr. Brooke in the *rhombohedral* system, and which, therefore, (if Sir David Brewster's law were universally true) should have but *one* axis of double refraction. Sir D. Brewster found, however, that the crystal had two optic axes; and it followed, therefore, either that it was an exception to the general rule, or that the measurement of its primitive form, made by two distinguished crystallographers, was inexact. The latter proved to be the truth. On a new and careful measurement of the angles of the crystal, Mr. Haidinger found that the primitive form was not the *right* hexagonal prism; and, therefore, that the crystal did not belong to the rhombohedral or hexagonal system. The angle between the sides of the prism and the ends was 90° 29′ instead of 90°; and it consequently belonged to one of those forms which possess two axes of double refraction. This instance is but one among many which might be adduced to show the value of the optical properties of minerals in classification.

The preceding laws are in singular accordance with the conclusions of the wave-theory of light. According to that theory, it is well known, *light* consists in the vibrations of an elastic *ether*, which are propagated from the shining body to the eye; just as *sound* consists in the vibrations of the *air* which are propagated from the sounding body to the ear. As long as this ether remains of the same density and elasticity, the direction of the propagated motion remains unaltered, and the light continues to move in a right line; but when it encounters a medium in which the density of the ether is different from that in the surrounding space, the direction of the wave will be altered, and the ray will be bent or refracted. The phenomena of light in crystals (according to the same theory) arise from a difference of density and elasticity of the ether in different directions within the crystal. If we take two lines at right angles, in the direction of the *greatest* and *least* elasticity of the ether within the crystal,—these, together with a third line at right angles to both, constitute what in Fresnel's theory are called the *axes of elasticity*. Now, when the elasticity is different in each of these three directions, it can be shown that the crystal will have two axes of double refraction, situated in the plane passing through the greatest and least axis of elasticity, and equally inclined to one of them. When the elasticity is the *same* in the direction of two of the axes, but greater or less in that of the third, the two *optic* axes unite, and the crystal is *uniaxal*. And, finally, when the elasticity is the same in the direction of all the three axes, it will be the same throughout the crystal, and the substance will be single-refracting.

These results of theory are confirmed in a very remarkable manner by the laws of Sir D. Brewster. It has been already mentioned, that the only crystals which do not possess the property of double refraction, are those belonging to the *tessular* system; *i. e.* those whose fundamental form is the cube, or *hexahedron*. Now, in this and its derived forms, it will be seen, we can assign three lines at right angles to one another, round which the whole figure is symmetrical; and we may therefore reasonably conclude that the density and elasticity of the crystal is the same in each of these directions, and, consequently, the same throughout. Again, crystals with *one* axis of double refraction belong either to the *rhombohedral* or the *pyramidal* system—systems whose fundamental forms are the *rhombohedron* and the *straight pyramid*. In each of these crystalline forms there is *one axis of figure*, or one line round which the whole is symmetrical; and we may, therefore, reasonably conjecture that the elasticity of the crystal is either greater or less in this direction than in others, while it is equal in all directions at right angles to it. The axis of form is in this case also the axis of double refraction. Finally, in the *oblique pyramid*, which is the fundamental form of the *prismatic* systems, there is *no one line*, or *axis of figure*, round which the whole is symmetrical; and it is, therefore, probable that the density of the crystal is unequal in all the three directions. Such crystals are found to have *two optic axes*.

It has been just stated, that in uniaxal crystals the optic axis is also the *axis of form*. In biaxal crystals, it did not at first appear that the optic axes were in any way related to the lines which bound the elementary crystal. Sir D. Brewster, however, ascertained that if two lines be taken, one bisecting the acute, and the other the obtuse angle contained by the optic axes, these (together with a third line at right angles to both) are closely connected with the primitive form. These lines are also the *axes of elasticity* of Fresnel's theory, and are considered by him to be the *true axes of the crystal*.

In what has preceded, we have assumed that the density and elasticity of a crystal is different in different directions, and that these differences are indicated by the fundamental form. Any one who considers the nature and phenomena of crystallization, can scarcely doubt of this. We are compelled to admit, that the forces with which the particles of bodies cohere to form a mass, are not the same on all sides; or, in other words, that these particles are endued with a certain *polarity*, by which they are made to assume a regular arrangement in the process of solidification; and, consequently, that the forces with which the crystallized mass resists compression or dilatation, must be very different according to the direction in which the compressing or dilating forces are applied. But we are not without direct proof of this. A difference of elasticity of crystals in different directions has been clearly established by the laws of their acoustical vibrations, as observed by M. Savart; and the same thing is even yet more distinctly proved by the effects of heat, by which they are, in general, dilated differently in different directions.

But to complete the connexion which is here traced between the laws which govern the crystalline form, and those which determine the action of the crystal on light according to the wave-theory, we must further suppose that the vibrating medium, or ether, within the crystal is connected with it in such a manner, that the density and elasticity of the one are dependent on those of the other. This must be supposed, if the particles of the ether and those of the body in which it resides be allowed to exert any mutual action at all; and this being granted, it follows that the molecular forces which determine the form of the crystal, determine also the constitution of the ethereal medium within it on which all its optical properties depend.

These things are here noticed, to show the *very close* connexion which subsists between the form of the crystal and its action upon light, when we admit the principles of the wave-theory. But the general laws discovered by Sir D. Brewster subsist independently of all hypotheses whatsoever, and establish a relation between the optical properties of crystals and their external characters, which, however it may tend to confirm the now popular theory of light, cannot be shaken by its overthrow. These relations are so close and intimate, that any change (however produced) in one of these classes of properties, is found to be accompanied by a corresponding change in the other. Thus fluor-spar belongs to the tessular system, and is accordingly singly refractive; but if pressure be applied to two of its opposite faces, so as to alter the form, it is found to *acquire* the property of double refraction.

This curious fact was discovered by Sir David Brewster; and he found that he was able to impart a double-refracting structure by the same means, not only to crystals which did not possess the property naturally, but even to uncrystallized bodies, such as glass and jelly. The same effects were produced by unequal exposure to heat; the effect of such exposure being to dilate the substance to which it was applied *unequally*, and therefore to produce the condition on which the property of double refraction depends.

Thus, if heat be transmitted from the surface to the axis of a cylinder of glass, by immersing it in heated oil, it is found to acquire the structure of a negative crystal with one axis, the axis of the cylinder being the axis of double refraction. This property is temporary, and is lost as soon as the glass becomes uniformly heated, and therefore uniformly dilated. If the cylinder, when in this state, be made to cool rapidly at the surface, by surrounding it with a good conductor of heat, it will transiently assume the opposite state of a positive double-refracting crystal. It is even possible to arrest the glass in one of these transient states, and thus to obtain a substance permanently endued with a double-refracting structure. For this purpose, it is only necessary to bring the glass to a red heat, and then to cool it rapidly at the edges. As the outer parts (which are more condensed than those within) assume a fixed form in cooling, the interior parts must accommodate themselves to that form, and therefore retain a state of unequal density; the law of the variation of density, and therefore the double-refracting structure, depending on the external form of the solid.

Again, as the double-refracting structure may be *imparted* to bodies in which it does not naturally reside, by compression or dilatation, so, by the same means, it may be *altered* in those bodies which already possess it. The most remarkable effect of this nature is that produced by the application of heat to crystals. The effect of such application, Professor Mitscherlich has discovered, is to dilate the crystal, in general, *differently in different directions*, and so to produce a change of form; and it has been since found that the double-refracting properties undergo a corresponding change. Thus the rhomboid of Iceland spar is dilated by heat in the direction of its axis, while it actually *contracts* in directions perpendicular to it. The angles of the rhomboid are thus altered, and it approaches the form of the cube, which, we have seen, belongs to crystals that are destitute of the property of double refraction. M. Mitscherlich conjectured, accordingly, that its double refraction would undergo a corresponding diminution; and experiment fully verified the conjecture.

The two rays, into which light is divided on entering a double-refracting crystal, are found to be endued with properties which distinguish them altogether from *solar light.* The light of the sun, or of any self-luminous body, is separated by double refraction into two portions, which are *always of equal intensity.* But if either of these portions be again divided by double refraction, it is found that its parts are no longer equally intense; that their relative intensity depends on the position of the second crystal with respect to the first; and that there are two such positions in which one of the rays vanishes altogether.

This remarkable phenomenon was first discovered by Huygens. It may be easily observed, by placing a second rhomboid of Iceland spar to receive the rays refracted by the first. It will be then seen that, when the two crystals are *similarly* placed, the ray which has undergone *ordinary* refraction by the first, will also undergo *ordinary* refraction by the second; and the ray which has suffered extraordinary refraction by the first, will also be refracted extraordinarily by the second. On the contrary, when the second crystal is turned round into a position at right angles to the preceding, the *reverse* takes place; the ray which has been refracted according to the *ordinary* law by the first, undergoing *extraordinary* refraction in the second; and *v. v.* And finally, in all intermediate positions, each of the rays refracted by the first crystal will be divided into *two* by the second, and will suffer *both kinds* of refraction.

Here, then, it is evident, each of the rays into which the pencil is divided by the first crystal, has acquired properties which distinguish it altogether from *common* light. It has, in fact, acquired *sides.* For we find that the refractions which it subsequently undergoes, depend on the position of the second crystal with respect to these sides; and that the same ray which undergoes *ordinary* refraction in one position of the second crystal with respect to it, will undergo *extraordinary* refraction in an opposite position. This modification of light is termed *polarization.*

But this modification of light may be impressed by other means. Thus Malus discovered that when a ray of common light is *reflected* from glass or water, or any transparent substance, at certain angles, the reflected ray has all the characters which belong to one of the pencils into which light is divided by double refraction. When received on a rhomboid of Iceland spar, it will undergo *ordinary* refraction in one position of the rhomboid with respect to the ray; *extraordinary* refraction in another position at right angles to the former; while in intermediate positions it will be divided into *two,* which are in general of unequal intensity. If, instead of transmitting the ray through a rhomboid of Iceland spar, we receive it upon a *second reflecting surface,* similar to the first, and at the same angle, the light will be *most* copiously reflected, when the plane of the second reflexion *coincides* with that of the first, and it will *vanish* altogether when it is perpendicular to it.

An apparatus consisting of two such reflecting plates—arranged in such a manner that the light reflected from the first, at a certain angle, may fall upon the second at the same angle, while the *plane* of the second reflexion is capable of being altered at pleasure—is, from its importance in experiments on polarized light, denominated a *polarizing apparatus.* The first reflector is usually called the *polarizing plate;* and the second, for reasons which will presently appear, the *analyzing plate.*

Now let such an apparatus be adjusted so that the plane of the second reflexion may be *perpendicular* to that of the first. In that case, we have seen, the light reflected at the first surface will be *wholly transmitted* through the second; and no portion of it whatever reflected. No change will be made in this phenomenon if a plate of *glass,* or any *single-refracting* substance, be interposed between the two reflectors. But the case is different if the interposed plate be cut from a *double-refracting* crystal. In this case, we shall find, the light undergoes a change which restores to it the capacity of reflexion at the second surface; and the quantity of light there reflected will be found to vary with the *thickness* and *position* of the interposed crystal.

When the crystalline plate is of moderate thickness, the reflected light is *white.* But when the thickness is much reduced, the most gorgeous colours appear, which vary with every change of inclination of the plate to the polarized beam. *Mica* and *sulphate of lime* are very fit for the exhibition of these beautiful phenomena, because they can be readily split by the knife into plates of almost any required tenuity. It is found that when thin plates of either of these substances are interposed between the two reflectors, so as to receive the polarized beam perpendicularly, the tints they produce vary with the thickness of the plate; these tints *rising in the scale* as the thickness is diminished—until, finally, when it is reduced below a certain limit, the colours wholly disappear, and the field appears *black* as when the plate is removed.

When the crystalline plate is turned round in its *own plane,* —being always perpendicular to the polarized beam,—the *tint* does not change, but varies only in *intensity;* that intensity being a maximum in two positions of the plate at right angles to one another, and vanishing altogether in two intermediate positions. If, on the other hand, the *analyzing plate* be turned, so as to alter the plane of the second reflexion, the colours will be observed to vary in the most striking manner; and it will be found that the colour reflected in any one position of the analyzing plate, is always *complementary* to that which it reflects in the perpendicular position.

All these curious and complex phenomena are consequences of double refraction. It is a well known law of light, that if two rays proceed from the same source, and one of them be a little retarded, the intensity of the light resulting from their union will vary greatly with the magnitude of the interval. When the component lights are of equal intensity, and the interval of retardation is an *even* multiple of a *certain length*, the resulting light will be *quadrupled.* When, on the other hand, that interval is an *odd* multiple of the same length, the resulting light will vanish altogether, and the two lights by their union produce *darkness.* This law is well known under the name of *interference*, and it is an immediate and necessary consequence of that theory which supposes light to consist in the undulations of an elastic fluid. The length, on which the laws of interference thus depend, is *half the length of a wave;* and its magnitude is different for the light of different colours.

The interval which gives rise to these phenomena may be produced in various ways. One of the rays, for example, may travel over a *greater space* than the other. This takes place when light falls upon a *thin plate* of a transparent medium. A portion of the light is reflected from the *first* surface of the plate; another portion enters the plate, and is in part reflected from the *second* surface; and it is obvious that when these two portions meet, the latter shall have traversed a space greater than the former, by double the thickness of the plate. It will therefore *interfere* with it, and produce all the phenomena of colour which we witness in thin plates.

A similar effect may be produced by *double refraction*, as well as by double reflexion, provided the two portions into which the ray is divided, on entering a double-refracting crystal, traverse it with *different velocities.* Now such is actually the case in all double-refracting substances. Consequently, when a ray enters such a substance, one of the portions into which it is divided will outstrip the other, and there will be an interval between them at emergence, depending on the *length of the path* traversed by the rays, and the *difference of the velocities* with which they have described it. When the crystalline plate is *thin,* this interval will be small; and as the two portions are then superposed at emergence, they must produce all the phenomena of interference.

Thus, for example, if the interval of retardation be an *odd* multiple of half the length of a wave of *red* light, the red light in the two pencils will be wholly destroyed by interference, and the resulting light will be of a bluish tint. If, on the other hand, the interval be an odd multiple of the length of a wave of *blue* light, the blue will be obliterated from the emergent pencil, and the resulting light will be of a reddish hue.

But here we are met by a difficulty. So far as this explanation goes, the phenomena of interference, and of colour, should be produced by the crystalline plate alone,—in *common light*,—and without either a reflector to polarize the *incident*, or to receive the *emergent* light. This, however, is not the fact; and the chief difficulty in this case is, not so much to explain how the phenomena *are* produced, as to show why they are *not always* produced. The solution of this difficulty is derived from certain laws of interference peculiar to polarized light, into which it would be foreign to the present subject now to enter. It is only necessary to observe, that the two rays, into which a single ray is divided on entering a double-refracting crystal, are *polarized* and in *opposite* planes; that of such rays those parts only can interfere whose planes of polarization are brought to coincide; and that it is further requisite that the original ray to which they belonged shall have been polarized in a single plane. Hence the necessity of the analyzing and of the polarizing plates.

The tint developed by interference depends, it is obvious, on the interval of retardation of the interfering pencils. This interval can be easily deduced from the laws which govern the velocities of the two refracted rays; and it is found that, in *uniaxal* crystals, it is proportional to the thickness of the crystal traversed by the rays, multiplied by the *square of the sine* of the angle which their direction makes with the optic axis; while, in *biaxal* crystals, it is proportional to the same thickness, multiplied by the *product of the sines* of the angles which the direction makes with the two axes. Hence, if a pencil of diverging rays be transmitted through a plate of uniaxal crystal, cut perpendicular to the axis, the interval of retardation,—and therefore the colour,—will be the same for all rays equally inclined to the axis; so that the colours will be disposed around the axis in *concentric circles*. In biaxal crystals, on the other hand, the interval of retardation will be the same for those rays, for which the product of the sines of the inclinations to the two axes is the same; and it is easy to deduce from thence that the coloured bands will be the curves called by geometers *lemniscates;* whose fundamental property is—that the rectangle under the lines, drawn from any point to two fixed poles, is a constant quantity.

It is a consequence of the law just stated, that, when the direction of the ray coincides with an optic axis, the interval of retardation vanishes. The two rays, in fact, proceed in this case with a common velocity, and can no longer be separated by refraction. The optic axis is, indeed, in all respects a neutral line with regard to the action of the crystal on the intromitted ray. If the ray sent in this direction be originally unpolarized, it will remain unpolarized; if it be polarized, its plane of polarization will be unchanged.

There is, however, one remarkable exception to these general laws,—an exception presented by one of the most common and familiar substances of the mineral kingdom. If we take a plate of *rock-crystal*, cut at right angles to the axis, and let fall upon it perpendicularly a beam of polarized light of any simple colour, we find that the plane of polarization of the emergent beam is entirely different from that of the incident. In some crystals the plane of polarization is turned from *left to right*, or in the direction of the hands of the dial-plate of a clock, while in others it is turned in an opposite direction; and the crystals themselves have been accordingly denominated *right-handed* or *left-handed.* This phenomenon was first observed by M. Arago.

The laws of this phenomenon were discovered by M. Biot, and are as follow:

1. In different plates of the same crystal, the rotation of the plane of polarization is always proportional to the *thickness* of the plate.

2. When two plates are superposed, the effect produced is very nearly the same as that which would be produced by a single plate whose thickness is the *sum* or *difference* of the thicknesses of the two plates, according as they are of the *same* or of *opposite* denominations.

3. The rotation of the plane of polarization is very different for the different rays of the spectrum, and increases with the refrangibility. Thus, the arc of rotation, produced by a plate of rock-crystal a millimetre in thickness, is 17½° for the extreme red of the spectrum, 30° for the rays of mean refrangibility, and 44° for the extreme violet.

From the third law it follows, that if the beam incident on the crystal be *white* or compound light, the emergent beam, after reflexion by the analyzing plate, will be richly coloured. For, the arc of rotation of the different simple colours being different, they will emerge from the crystal polarized in different planes; and, consequently, they will be reflected by the analyzing plate in different proportions. Thus, the rays whose plane of polarization coincides with the plane of reflexion from the analyzing plate, will be reflected most abundantly; the quantity of the reflected light will diminish as the inclination of the plane of polarization to the plane of reflexion increases; and for those rays, whose plane of polarization is perpendicular to the plane of reflexion, it is null. Thus the reflected light will contain the several simple colours in proportions very different from that in which they exist in solar light, and will be therefore coloured; the colour changing in the most beautiful manner as the plane of reflexion is varied.

The curious distinction between plates of different crystals, (and which, it has been already stated, gave rise to the denominations "right-handed" and "left-handed,") for some time added to the mystery of this subject. At length, however, Sir John Herschel discovered a connexion between the phenomena and the crystalline form. The ordinary form of the crystal of quartz is the six-sided prism, terminated by a six-sided pyramid. The solid angles at the junction of the pyramid and the prism are sometimes found replaced by secondary planes, which are oblique to the original planes of the crystal; and the variety is thence denominated *plagiedral.* Now it is found that in the same crystal these planes *lean* all in the same direction; and that when that direction is *to the right,* (the apex of the pyramid being uppermost,) the crystal is *right-handed;* and that, on the contrary, it is *left-handed* when the planes lean in the *opposite* way.

Sir David Brewster has since observed a remarkable peculiarity in the *amethyst,* or violet quartz, in connexion with these properties. He found, in fact, that it was composed of *alternate layers* of right-handed and left-handed quartz. This very remarkable structure is in some measure indicated by the *fracture* of the mineral; for the edges of the layers *crop out,* and give a peculiar rippled appearance to the surface. But the structure is fully displayed by the aid of polarized light, on introducing a plate of the crystal between the two reflectors.

It remains to say a few words of the *absorption* of light by crystals.

Coloured crystals present two remarkable phenomena, both due to absorption. In the first place, the *intensity* and the *colour* of the transmitted light is found to vary, in general, with the direction; and crystals which are of one colour, when viewed by light transmitted along the axis, exhibit a colour entirely different when viewed in a transverse direction. This property of *dichroism,* as it is called, was first observed by Dr. Wollaston in certain crystals of *palladium.* It is very remarkable in the *dichroite,* a mineral which takes its name from the property; and it has been found by Sir D. Brewster to exist, in a greater or less degree, in all coloured crystals. Sir D. Brewster has, in fact, shown that the two pencils, into which a ray of common light is divided on entering a coloured crystal, are, in general, *differently absorbed;* and, consequently, differ both in *intensity* and *colour* at emergence. This difference, in uniaxal crystals, was found to depend on the inclination of the ray to the axis—being greatest when the ray was perpendicular to the axis, and vanishing when it coincided with it. The light resulting from the union of these two pencils will therefore vary, both in intensity and colour; so that when common light is transmitted perpendicularly through different plates of the same crystal, the strength and tint of the transmitted light will depend on the inclination of the surfaces of the plate to the axis. Analogous properties exist in biaxal crystals.

Another effect of the absorption of light in crystals is, that the emergent light is, in general, *partially polarized.* This is manifestly the result of the *unequal absorption* of the two oppositely polarized pencils. The property exists, in a very remarkable degree, in the *tourmaline,* in which it was discovered, about the same time, by M. Biot and Dr. Seebeck. The difference of intensity of the two pencils increases, of course, with the thickness of the crystal traversed; and, when that thickness is sufficiently great, the absorption of one of the pencils will be, as to sense, complete, and the polarization of the transmitted light apparently perfect. Plates of this crystal, cut parallel to the axis, are accordingly much used in experiments on polarized light. *Smoke quartz* also possesses the property to a considerable degree.

H. L.

NOTICE OF ANIMALS WHICH HAVE DISAPPEARED FROM IRELAND DURING THE PERIOD OF AUTHENTIC HISTORY.

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(Read on 14th December, 1836.)

At a period of no great antiquity, many species of wild animals existed in Europe, which have disappeared before the progress of improvement. It is well known that the beaver, the wolf, and the bear were once natives of England; and wild cattle were formerly abundant in the forests of Scotland. In the present paper, I shall attempt to collect some information respecting the ancient Fauna of Ireland, and to ascertain what species have been lost since the twelfth century; and also to notice such species as have had their numbers much diminished, although they still exist in the country.

1. *Martins.*—Under this head, I shall include the different vermiform carnivoræ which are natives of Ireland. It appears that Ireland still possesses all the species of this group which are natives of England, and, consequently, that none of them has been extirpated; but they are now much less abundant than formerly, as will appear from the following quotations:— Even so late as the sixteenth century, martins' skins appear to have been an article of commerce in the province of Ulster. Peter Lombard, in his work entitled De Regno Hiberniæ Insula Sanctorum, after mentioning the wild boar and the wolf as common in Ulster, has the following observation:—“ Præcipue *martes, quorum pelles plurimum estimantur*, et in universum in animaliaum magna pars est sita devetiarum hujus regionis.” * At a subsequent period, when the forest begun to be cut down, and agriculture was more attended to, the martin tribe was regarded as vermin; and various laws were enacted to encourage their destruction. The 11th of Anne, c. 7, offers a reward for the destruction of birds and beasts of prey, viz. the otter, heron, kite, weasel, &c. Still later, in the 17th of George II., a reward is offered for killing otters, weasels, martins, herons, kites, &c., and water rats, commonly called Norway rats.

2. *The Wolf.*—Great numbers of wolves formerly existed in Ireland, and they maintained their ground in this country for a longer period than in any other part of the empire. Campion, whose History of Ireland was published in 1570, informs us that wolves were objects of the chace. “ They (the Irish) are not,” he says, “ without wolves, or greyhounds to hunt them, bigger of bone and limme than a colt.” A century later, they appear to have been equally abundant; for we find, by the Journals of the House of Commons, that, in 1662, Sir John Ponsonby reported, from the committee of grievances, that a bill should be brought in to encourage the killing of wolves and foxes. Effective measures for this purpose appear to have been taken; and the wolf was at last extirpated about the year 1710. Dr. Smith, in his History of Kerry, when speaking of certain ancient enclosures, observes, that “ many of them were made to secure cattle from wolves; which animals were not finally extirpated till the year 1710, as I find by presentments for raising money for destroying them, in some old grand jury books.”

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* Peter Lombard was born in Ireland in 1560; died at Rome, 1625. See a notice of his book in the Anthologia Hibernica.

† *Smith's Kerry, p. 173.*

3. *The Wolf Dog.*—The wolf dog must now be included in the list of lost animals, although the date of its disappearance is within the memory of people still living. This race appears to have been unknown to the Romans, although that people appear to have put a high value on British dogs. Oppian, who has given a good description of the Scotch terrier, does not notice the Irish wolf dog. Perhaps this Irish wolf dog is alluded to by Symmachus, a writer of the fourth century, who informs us that seven Irish hounds (septem Scotii canes) were exhibited in the Circus at Rome; where they excited admiration, on account of their strength and fierceness. The Irish wolf dog was a very distinct race from the Scotch hound or wolf dog; which resembled the Irish breed in size and courage, but differed from it by having a sharper muzzle and pendent ears.

4. *The wild Boar.*—The wild boar was formerly the most abundant of the wild animals of Ireland. According to Giraldus Cambrensis, they occurred in vast numbers; but they were a small, deformed, and cowardly race.* They continued to be plentiful down to the seventeenth century. I have not been able to ascertain the date of their extinction.

5. *The Red Deer.*—The red deer, if not extinct, has had its numbers greatly diminished; but it is still found in Kerry, and also in Galway. In the ninth century, when the state of the country afforded them protection, they appear to have attained a very great size. Giraldus speaks of them as "Cervos præ nimia pinguedine minus fugere prævalentes, quantaque minores sunt corporis quantitate tanto præcellentius efferuntur capitis et cornuum dignitate." We have quoted the passage at length, because both Wittaker and Dr. Hibbert are inclined to believe that it applies to the extinct elk: an opinion which, however, does not appear to be borne out by the passage before us. Giraldus, who has described minutely many smaller animals, could scarcely have passed over the elk, had it then been in existence, with so slight a notice. There appears to be no difficulty in referring the passage to the red deer, especially as the horns of this species, which are found in bogs, often exceed in size those of the present race, which are seldom allowed to attain their full developement. Very few red deer are now truly wild in Ireland, although several laws have been enacted for their preservation. The 11th of Anne, c. 7,

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* Aprorum quidem et sylvestrium porcorum nusquam terrarum tantam copiam vidimus; sunt tamen exigue, deformes, et fugitivi, nec minus audacia et animositate quam corporis compositione degeneres.—*Girald. Top. Hibern.*

imposes a penalty on shooting red deer without permission; and a similar law was enacted during the reign of William the Third.

Several species of birds have also disappeared, some of which were once very abundant. The crane (Grus cinerea) was formerly so plentiful, that, according to Giraldus, flocks, consisting of a hundred individuals, were extremely common.* Smith, in his History of Cork, observes, that several of them were seen during the severe winter of 1739; " but," he adds, " they do not breed with us."

The stork (Ciconia nigra) was also a native of Ireland, but was esteemed a rare bird even so far back as the time of Giraldus.†

The bustard (Otis Tarda) remained with us till so late as 1750; when they do not appear to have been very rare in the county of Cork.

The cock of the woods (Capercailze Tetrao uragalus) was, according to Giraldus, more common than the grouse during the twelfth century. The Capercailze was called, by Giraldus, Pavo sylvestris; and he informs us that they were abundant, while the grouse (Grutæ) were rare.‡ The extinction of this fine bird was simultaneous with the destruction of the pine forests. The act of 11th Anne, c. 7, prohibits altogether the shooting of " that species of the cocks of the wood, a fowl peculiar to Ireland, which is likely to be lost." It remained in the county of Cork till so late as 1750. §

These statements may be considered as giving a pretty accurate account of such animals as were formerly inhabitants of Ireland, but which are now extirpated, or have had their numbers greatly diminished. If we now compare the account of the extinct animals of Ireland with the history of those which have disappeared from Britain, we will find several remarkable deficiences in the Irish list. No mention has been made of the bear, the beaver, the wild ox, or the fallow deer; and if animals so remarkable from their size and habits, have escaped all notice on the part of the older writers, the legitimate conclusion appears to be, that, like the adder and blind worm, they were not indigenous to the country.

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* In tanto vero numerositate se grues ingerunt ut uno in grege centum et circiter numerum frequenter invenies.—*Top. Hibern.* p. 705.

† Ciconiæ vero per totam insulam rarissimi sunt illæ nigræ.—*Girald. Top. Hib.* 707.

‡ Pavones sylvestres hic abundant, gallinæ vero campestres, quas vulgariter grutas vocant raræ sunt perdicibus tamen in quantitate quam colore persimiles.—*Top. Hib.* 706.

§ For this and the other quotations from the Statute Book, I am indebted to my friend, T. Whitla, Esq.

With respect to the bear, I have not found any indication that it was a native animal; while several testimonies of an opposite tendency may be quoted. At a period when the bear still maintained its ground in Britain, it is natural to expect that its absence from Ireland should excite attention, as the absence of poisonous reptiles is so often alluded to at present. The Venerable Bede, accordingly, informs us that the only ravenous animals found in Ireland were the wolf and the fox. Giraldus makes no mention of the bear. What is still more conclusive, in a poem by St. Donatus, Bishop of Fesole, who died in the year 840, it is expressly stated that the bear was not a native of Ireland:—

> "Ursorum rabies nulla est ibi, sæva leonum,
> Semina nec unquam Scotica terra tulit;
> Nulla venena nocent, nec serpens serpi in herba,
> Nec conquesta canit garrula rana lacu."

The beaver was formerly a native of England, Wales, and Scotland, as is sufficiently attested by the accounts of the older writers; and also by the decisive fact, that its remains have been disinterred from bogs in several localities. We have neither kind of evidence that it ever existed in Ireland; and the only authority which we can quote, proves quite the contrary—Giraldus, who was aware that the beaver existed in England at the time when he wrote, denies that it was a native of Ireland:—Taxos Hibernia non castores habet. Habetur tamen in Guallia Teynense autum in flumine apud Kaerdygan, habentur etiam in Scotia similiter rari.—*Top. Hib.* p. 709.

Much importance is due to the opinions of Giraldus on this subject: he has given a very complete account of the animals of Ireland; and also appears to have been an attentive observer, and one who was well acquainted with the localities of the beaver in Britain. It appears, therefore, that the geographical range of the beaver did not include Ireland: and I have never heard of any instance in which the bones of this animal have been disinterred from our bogs.

With respect to the ruminating animals, our information is not so satisfactory; but, I think, the evidence which we do possess, goes far to prove that neither the fallow deer, the roebuck, nor the wild oxen, such as are still in some parks in England, were not indigenous in Ireland. The testimony of Giraldus appears to be decided as to the two first of these animals, for he includes them in his catalogue of animals not natives of Ireland:—Defectum vero et aliarum quarundam patitur insula. Caret enim cœpreis caret, et clamis caret, &c.

The only objection that I am aware of, to this assertion of Giraldus, is the fact mentioned by Smith in his History of Kerry. "The mountains," he says, "were frequented by herds of fallow deer, that range abroad in perfect security, nobody disturbing them in these wild places." It is not improbable that these fallow deer were introduced from England.

Two races of oxen were formerly inhabitants of Britain: the one of great size, whose horns are found in bogs, but of whose existence we have no traditionary evidence. These horns have attracted attention for a long time; and a very good figure of them is given by Gesner, who obtained his specimen from England. It is remarkable that no indication of the former existence of this race of oxen in Ireland has yet occurred, nor could I obtain any evidence that they have ever been found in the bogs of this country.

The second and smaller race is still pastured in England, and was abundant in the Scotch forests at no very remote period; but, like the greater race, we have yet no evidence that it ever was a native of this country.

OBSERVATIONS ON THE LIGNITES AND SILICIFIED WOODS OF LOUGH NEAGH.

BY JOHN SCOULER, M.D. F.L.S. &C. PROFESSOR OF MINERALOGY, ROYAL DUBLIN SOCIETY.

(Read Wednesday, January 11, 1837.)

The occurrence of silicified wood around the margin of Lough Neagh, has attracted attention from a very remote period, and was long regarded as one of the wonders of Ireland. It may, therefore, be of interest, before considering the geological relations of the fossilized woods, to give a brief outline of the various opinions which have been entertained respecting the supposed petrifying powers of the waters of Lough Neagh. The earliest author who makes mention of these petrifying properties is Nennius, an English writer, who flourished some time between the seventh and ninth centuries; but we have no reason to doubt that the existence of silicified woods, on the shores of Lough Neagh, had been observed by the natives long before the time when Nennius wrote. The writer we have mentioned informs us, that the lake called Lough Neagh has the property of changing wood into stone; that wood is cut and deposited in the lake, and that, after a year has elapsed, the wood is changed into stone.[*] Higden, a writer of the fourteenth century, gives a still more wonderful account, for he speaks of a lake in Ireland, into which, if a piece of wood be inserted, that portion which is fixed to the soil becomes iron, that which is surrounded by the water becomes stone, while the part which is above the water remains wood.[†] Every species of wood was not believed to be equally capable of undergoing those metamorphoses; and it was supposed that the wood of the holly had the greatest aptitude to be changed into iron and stone. These fables were credited not only in Ireland, and were current among English writers, but they found their way into the works of several continental authors.

Dr. Boate, whose work was published in 1652, is the earliest writer on the natural history of Ireland; and he expresses himself with considerable hesitation respecting the petrifying properties of Lough Neagh. Dr. Molyneux, in a communication which he made to the Royal Society in 1684, contends for the silicifying powers of the lake. His correspondent, the Rev. Mr. Smith, to whom Dr. Molyneux had addressed a series of questions on the subject, arrived at a very different conclusion. Mr. Smith, who resided in the vicinity of the lough, had observed that many specimens of fossil wood were found at a great distance from the shores; and hence he concluded that the petrifying property belonged rather to the soil than to the water.

The next writer who has treated of Lough Neagh is Barton, whose work, entitled Lectures on the Natural History of Lough Neagh, made its appearance in 1757. This book abounds in much useless matter, but is, at the same time, far richer in new and valuable facts, than any preceding publication on the subject. Barton lived in the vicinity of the lake, and was indefatigable in gaining information, and collecting fossil woods, of which he obtained several hundred specimens. Some of his specimens were of considerable size, one of them weighing no less than 700 lbs. It is also deserving of notice, that he mentions one specimen, in which the wood had been changed into iron pyrites. But by far the most important information which he communicates is that which relates to the geological relations of the fossil woods, and their associated lignites or black coal. He states, that, at a place called Abaness,* which is nearly opposite Ram Island, and not far from Glenavy Waterfoot, the silicified wood is found in a bed of lignite which is covered by a stratum of clay. At the above-named locality, there is a bank on the shores of the lake: the bank is twelve feet high, and about ninety feet distant from the water. Under the bank the following section was obtained by digging:—"The upper stratum was a bed of red clay, three feet deep; the second, a stratum of blue clay, four feet deep; the third was a stratum of black wood, four feet in thickness, which reposes on another stratum of clay. This stratum of wood is of one uniform mass, and capable of being cut with a spade. Sometimes the wood will not easily break: in that case, it requires the aid of some other tool to separate it from the mass; and may, if properly done, afford a block of two, three, or four hundred pounds; which, being carefully examined, is found to consist more or less of stone."† To Barton, therefore, the merit is due of being the first to ascertain the relation of the silicified wood to the lignite: I must add, that, in all matters of fact, I have found him a faithful and accurate guide.

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[*] Est aliud stagnum quod facit ligna durescere in lapides. Homines autem findunt ligna, et postquam formaverunt in eo usque ad caput anni, et in capite anni lapis invenetur, et vocatur stagnum Loch-euchæ.—Nennius, as quoted in Ogygia.

[†] Est lacus in hac terra, quo per si aliquod spatium palus ligneus infigatur, pars solo inhumeus fit ferrea, quæ in aqua est fit lapidea, sed quæ supra aquam est lignea manet.—Higden.

The wonderful qualities of Lough Neagh have been summed up in the following verses:—

“ Est lacus Ultoniæ Neachum quam nomine dicunt,
Cujus si quivis Aquelentam affigat ad imum,
In tres septennis species distinguitur annis;
Pars fundo ferrum, cos fluctibus, arbor aprico.”

Since the time of Barton, no original investigations seem to have been made concerning the fossil woods of Lough Neagh; and his work appears to have been the source from whence succeeding compilers have derived their materials. The theoretical part of Barton's work is, as might have been expected, the most unsatisfactory portion, and does not require any more particular notice. We shall only add, after this review of what has been written concerning Lough Neagh, that there is not any evidence of a satisfactory nature that the waters of the lake ever possessed the property of changing wood into stone. The following facts present insuperable objections to such an hypothesis. The property cannot reside in the waters of the lake, for the fossil wood is found only in particular localities. It is also found in the interior of the country; and none of the stakes which have been fixed into the lake, or the trees which grew on its shores, have been in any degree silicified. The following circumstance is equally decisive. Some years ago, the remains of an ancient canoe. such as could only have been used in the infancy of civilization, and consequently of great antiquity, was dredged up from under the waters of the lough, but no portion of it had been changed into stone.*

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* This name of Abaness is now obsolete; but the place it designated is not far from the entrance of the Glenavy into the Lough.

† Barton's Lectures on Lough Neagh, p. 96.

We shall now attempt to give some account of the lignites and silicified wood, and to ascertain the nature of the vegetation which afforded them. It is, however, an extremely difficult task to give any thing like a connected and complete history of the deposites of lignite which occur in various localities around the margins of the lake, and in many places in the adjacent districts. The nature of the country, covered to a great extent by a surface of peat, or, when that is absent, by accumulations of transported materials, leave the geologist scarcely any other resource than such artificial sections as a happy chance may afford. When we consider the slowness with which our knowledge has advanced respecting the crag of Suffolk, and the Bovey coal of Devonshire, the inevitable imperfections of the present attempt to give some account of the recent formations around Lough Neagh may, perhaps, be excused.

Deposites of lignite are found at different places around Lough Neagh, from Dungannon to Glenavy, forming a circuit of about twenty miles. The superficial formations which occur in this district, exclusive of the peat, are of two kinds, which it is necessary to distinguish. The inferior one consists of beds of clay and bituminous wood or lignite; and the upper, which consists of transported masses of gravel, which are usually called diluvium. The inferior formation, as Mr. Griffiths has observed, may be considered as analogous to the Bovey coal, or, perhaps, still more to the association of beds of clay, lignite, and volcanic rocks which are found in the basin of Neuwid on the Rhine. These beds are only accessible to examination at a few remote points; but we have evidence that they sometimes extend a good way inland, and also that they spread beneath the waters of the lake. Mr. Griffiths is the only writer who has noticed the beds of clay and lignite which occur at Verner's Bridge, on the edge of the Dungannon coal field. In this place the clay is extracted for the supply of the adjacent pottery, so that a portion of the strata have been disclosed.

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* Shaw Mason.

Beneath the accumulation of transported detritus there is a stratum of clay, of a white colour with a tinge of brown, and about two feet in thickness. This clay is succeeded by a stratum of fine white sand, about four feet in depth; and beneath this there is another bed of fine sand alternating with thin layers of carbonaceous matter, resembling leaves of trees. The wood or lignite which is found in this situation is of a black colour and loose texture, consisting of portions of stems of trees, sometimes retaining their bark: they obviously belong to the genus Pinus, and differ but little, in their state of preservation, from the ordinary bog timber of the country. It is interesting to observe, that the lignite of this locality is remote from any trap rock, and does not appear to have suffered any modification from the application of a high temperature. No silicified wood has been found in this locality.

The depth of this formation is unknown, and, from the state of the country, can only be ascertained by artificial sections; but we have sufficient evidence to prove that it is of great depth. Mr. Griffith informs us, that "several useless trials in search of coal have been made by boring in the clay district, one of which was 98 yards in depth, and many others more than 60 yards, and yet the under stratum beneath the potter's clay has not been sunk to in any instance."

Another deposite of lignite, in this instance accompanied by silicified wood, occurs on the shores of Lough Neagh, not far from Lurgan; but I have not had any opportunity of examining it.

A third locality is at the spot named Ahaness by Barton, which is opposite Ram Island, and a little to the south of the Glenavy river. At Glenavy, the bed of clay extends a great way into the lough, and near the shore it is covered by a great accumulation of transported matter; so that the lignite clay is only accessible for a short space between the water's edge and the banks of alluvium. In this place the lignite is sometimes extracted by the country people, in the deficiency of other fuel, although the smell which it exhales while burning is very disagreeable. The bed containing both lignite and silicified wood consists of a very tenacious blue clay, but contains occasionally small fragments of trap rocks and chalk. The wood coal is in this place of a more compact nature than at Verner's Bridge; but, like it, consists of the remains of fir trees, and is often silicified. Barton had long ago stated that specimens of silicified wood were found associated with the lignite in this quarter, and such also is the belief of the country people; but, to remove all hesitation on this head, a man was employed in digging till I could obtain specimens of both kinds of wood.

The lignite consists of portions of stems and branches of trees, but no roots were observed; but from the circumstance that many of the specimens still retain their bark, it is probable that they have suffered no lengthened transportation. The wood splits readily in the direction of its fibres; while in the transverse direction it is broken so as to display a smooth surface, as if it had been cut by some instrument. This is probably the result of some concretionary arrangement which has taken place subsequently to the deposition of the wood, and which appears more perfectly in the older and more altered coals of the carboniferous epoch. This lignite is also sometimes studded over with little crusts of calcareous matter, which have also penetrated the substance of the wood, forming small veins. This change is probably posterior to the silicifying process, and is, perhaps, at present in progress.

Like the analogous deposit at Verner's Bridge, the depth and extent of the ligniferous bed has not been ascertained, but must be very great. Donald Stewart, who examined this part of the country under the direction of the Royal Dublin Society, states that a fruitless search for coal was made in this quarter at Portmore:—"They bored through two beds of coal, or what is called black wood, 25 feet thick each, and a third stratum 9 feet thick and 80 yards deep; they bored 18 inches deep into a fourth stratum, having no more rods to go deeper."

The alluvial covering which spreads over these beds also deserves notice, as it frequently contains fragments of silicified wood, which may be collected many miles from the shores of the lake. This superficial accumulation may be studied to advantage along the shore to the south of the Glenavy, where it forms banks from twelve to twenty feet in thickness; good sections are also obtained by ascending the Crumlin or Glenavy rivers. This alluvium consists of a loose clay, containing numerous fragments of chalk and trap, with nodules of flint, and exhibits no marks of stratification. In some places, where the clay contains particles of chalk, and a degree of moisture is present, numerous concretions of calcareous matter are formed, which are obviously of a later origin than the formation in which they occur. They consist of rounded nodules of irregular forms: when broken, they are found penetrated by numerous fissures, resembling a septarium. A portion of some vegetable occasionally forms the nucleus around which the calcareous matter has arranged itself. Nodules of earthy carbonate of iron are also very common; but it is difficult to say whether they have been transported from some older formation, or have been formed in the same manner as the calcareous nodules. They are often of considerable size, weighing upwards of 20 lbs.: their shape is sometimes spheroidal; at other times irregular. They are obviously of a concretionary nature, like the septaria of the coal formations, and a piece of lignite is often found in their interior. These nodules have probably been formed *in situ*; at least, the presence of lignite in some of them would indicate that they have been produced after the deposition of the wood coal by the ferruginous silicates of the trap. This supposition is rendered still more probable from the fact, that earthy carbonate of iron is actually produced in this manner from the destruction of the trap fragments, which it afterwards cements into an exceedingly hard conglomerate. Such conglomerates are seen in several places around Lough Neagh.

Large fragments of silicified wood and lignite, particularly the former, are not uncommon in this accumulation of detritus. The petrified wood is usually rounded, and always of a white colour, from the loss of its carbonaceous matter; and this circumstance serves to distinguish them from the specimens found associated with the lignite in the clay, which are of a dark colour.

Besides these deposites of wood coal which are found on the margins of Lough Neagh, the lignite also occurs in many places under beds of trap, and even between two masses of basalt. At Kellymorris, in the centre of the county of Antrim, there is a bed of lignite which is covered by trap. It was formerly wrought to afford a supply of fuel, but of late it has been abandoned. This singular situation of the lignite occurs in the midst of a trap district, on the side of a small hill, whose summit consists of trap; and, even in its present abandoned state, portions of the lignite, in contact with trap, may be seen by those who have the patience to explore the old workings. The wood coal still retains its ligneous texture, but much more imperfectly than in that which is found on the shores of Lough Neagh; so that it is impossible, in this case, to ascertain to what tribe of plants the wood belonged. It is also remarkable, that in this, as in all the other cases in which the lignite occurs under trap in the county of Antrim, it still retains its bituminous ingredients, and burns with smoke and flame. This circumstance is accounted for by the pressure of the superincumbent trap.

Fossil wood, however, is found in other places, under the trap, in a much better state of preservation than at Kellymorris. Unfortunately, I have not yet had an opportunity of examining the lignite under trap which is found at Ballintry. The following notice of it is given by the Rev. R. Trail :—

" I have even seen the roots of the trees, and distinctly traced the ramifications, where they were not covered with basalt. The bark and knots are quite distinct, and you may reckon the rings of annual growth."* This is also the case with the wood which is found between beds of basalt at the Giant's Causeway; and which, as far as can be inferred from its aspect, is also coniferous, being very similar to the wood found under clay on the shores of Lough Neagh.

It now remains that we should give a more minute account of the silicified woods, and of their relations to the adjacent rocks. These silicified woods are not coextensive with the deposites of lignite: no specimens have been found at Verner's Bridge, near Dungannon, in the potter's clay and lignite which are found there; neither have any specimens been yet found in the lignites under trap in any locality throughout the country. If we take a survey of the district in which the fossil wood is found, we shall find that it extends from beyond Cranfield on the north, to the parish of Sego, in Armagh, on the south. If we travel along the shores of the Lough, between these points, we observe the silicified road at the mouth of the Glenavy river: thence, three miles inland, at the village of Glenavy. We also find it in the Crumlin river, at an equal distance from the lake; also at Longford Lodge; and again, in rolled pieces, at the mouth of the Main river, near Shane's Castle.

The line of coast which has been indicated also possesses another peculiarity; it also defines very accurately an interesting formation of trap, around the borders of which the silicified woods are found. This extensive mass of trap commences near Shane's Castle, where it was first observed by Captain Tucker.† The following remarks are, therefore, supplementary to his, and tend to prove that the formation is one of considerable extent. This trap is first seen near Shane's Castle, where it occurs under various interesting forms. The columns are of great regularity and beauty. The substance of the basalt is of an extremely homogeneous nature; and no aggregation of crystals can be detected in it. In some places it passes into a substance scarcely distinguishable from pitchstone; and, indeed, the general mass may be considered as intermediate between pitchstone and trap. When not columnar, it is not necessarily amorphous; but often consists of spheroidal concretions, varying from upwards of a foot in diameter to the size of a pea. These spheroids, especially the smaller ones, consist of concentric crusts, depending in this case on their primitive structure, and not the result of decomposition. Near the same place the trap has also assumed the form of polygons placed in contact with each other, and so artificial in appearance, as to suggest to a common observer that this basaltic pavement was the work of human skill. This little pavement, which does not cover much more than an acre, is not, like the Giant's Causeway, formed by the extremities of a multitude of columns, but by the compression and interference of a great number of spheroids, which have, in consequence, assumed every variety of polygonal configuration. I have not been able to trace this basalt continuously along the shores of the lake; but it reappears crossing the channel of the Crumlin river, where it consists of an aggregation of spheroids. It becomes again visible on the Glenavy, where it assumes the columnar form, and may be seen forming a small cascade near the bleach-green. There is another circumstance connected with this trap deserving of notice. At Shane's Castle, where amorphous, the trap is vesicular, that is, contains empty cavities; and hence cannot be called an amygdaloid. This observation is interesting, in as far as it affords a presumption that the melted trap was not exposed to a high degree of pressure. Its extreme fluidity is also highly probable, both from its homogeneous appearance, as if the result of the rapid cooling of a fluid mass, and also from the curious fact that, in some places, it has assumed a kind of stalactitic form, similar to what we observe in recent lavas which have spread upon the surface. This example is also deserving of notice, as the existence of empty amygdaloidal cavities in trap rocks was formerly denied by certain geologists.

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* Statistical Survey of Antrim.

† Notes on the Basaltic District of the North of Ireland, by Captain Portlock. Journal of Geological Society of Dublin, vol. I. p. 71.

This formation of trap, or, perhaps, pitchstone trap, appears to be in some way related to the silicified woods; at least, the two appear to be very nearly coextensive, and may possibly have more points of affinity than that of mere juxta-position.

After the attempt to sketch the geological relations of the fossil woods, it will be necessary to give some account of their characters, and to ascertain the class of vegetables to which they belong. It has already been stated that they are found in two varieties of position: in the first they are associated with the lignites under beds of clay; in the second, they appear nearer the surface, in accumulations of transported matter. In the first position they are of a dark colour, and scarcely distinguishable by the eye from the ordinary lignite. When more minutely examined, they are found in some cases to consist of a uniform mixture of carbonaceous and siliceous matter; and, when in this state, are very apt to be neglected, as it is difficult to detect the woody texture: in other cases, even the layers of growth can be easily observed. Very frequently, layers of woody matter still exist amid the siliceous substance; and, in that case, the two can be easily separated. All the specimens split readily in the direction of the fibres of the wood. They are frequently covered on the surface with minute but distinct crystals of quartz, which also penetrate their fissures. More rarely, a thin coating of chalcedony has been observed. From these circumstances, it appears improbable that they have ever been transported; for exposure to the weather whitens them, by removing the carbonaceous matter: and as they are usually angular, and have portions of wood adhering to them, or are studded over with crystals, they cannot have been exposed to attrition.

When found in the superficial alluvium, if long exposed, they are usually of a looser texture, from the loss of woody matters. Their colour, from the same circumstance, is white: and hence the notion that they were specimens of petrified holly. Nothing is more common than to find specimens which are black internally, and white at the surface; and any black specimen may be whitened by burning. It is in this state that most of the specimens are found, either when casually turning up the soil, or in the courses of streams.

The specimens vary in size; sometimes weighing nearly a ton, as in the splendid specimen preserved at Langford Lodge. They are also very abundant in some places: Barton says that upwards of two tons of them were disinterred at Abaness; and I have seen almost as many in a garden in the village of Glenavy.

It is an important point to ascertain the nature of the wood to which the specimens must be referred; and this task, which, but a few years ago, would have been almost impossible, is now comparatively easy. From a careful examination of the wood, it is apparent that it must be referred to the genus Pinus. Anxious to have a better authority than my own to vouch for this assertion, I transmitted sliced specimens to Dr. Lindley; who was so kind as to reply to my wishes, by giving as his opinion that the wood is undoubtedly that of a Pinus, either Pinus Strobus or Pinus Abies. The latter appears to be more probable, especially as the Weymouth pine (P. Strobus) is not a native of Europe; and it is at least probable that the spruce or Norway fir was once indigenous to Ireland. On this point it is hazardous to give a decided opinion: but all the evidence which I can quote is in favour of the fact, that the spruce fir was once indigenous. Ray, in his Synopsis of British Plants

(p. 442.) gives the Pinus Abies as a native of Ireland, on the authority of a Mr. Harrison, who, he says, was a good observer. Smith, also, the most scientific of all our topographers, is of the same opinion; and, from his well known accuracy as a botanist, much importance is due to his opinion on such matters. Speaking of the Abies Mas Theophrasti of Ray, or the spruce fir, which he takes care to distinguish from the Scotch fir, he adds:—"They grow wild in the rocky mountains which divide this county (Cork) from Kerry."* In his History of Kerry, he mentions that the Norway fir and Scotch fir were formerly wild in the mountainous parts of that county. †

ON A MANGANESE ORE, CONTAINING OXIDE OF COPPER FROM SWEDEN;

WITH REMARKS ON THE APPLICATION OF SUCH ORES TO THE PURPOSES OF MANUFACTURE.

BY EDMUND DAVY, F.R.S. M.R.I.A. &c. PROFESSOR OF CHEMISTRY TO THE ROYAL DUBLIN SOCIETY.

(Read April, 1837.)

The native oxides of Manganese ore have been so long known, they appear to have been so ably described by Mineralogists, and their composition so accurately determined by chemists; that little now remains to be done in this department. Little novelty can be expected from the re-examination of those ores, unless in reference to foreign substances they may contain, which may exert an important influence on certain manufactures in which such ores are employed.

I should not, perhaps, at any time, have thought the mere examination of a Manganese ore an object of sufficient interest to bring before this Society; but having been in the habit for many years, of occasionally examining Manganese ores, from different parts of the Globe, I lately, (for the first time), detected oxide of copper to a considerable amount, in a Manganese ore (otherwise pure), from Sweden. The admixture of copper ore with oxide of Manganese, is, I presume, very rare; as I looked in vain for the description of such an ore, in the latest editions to which I had access, of different Works on Mineralogy, as those of Hauy, Lucas, Brochant, Brongniart, Jameson, Thomson, and Kidd.* Now, as it is well known that in the manufacture of bleaching liquors and bleaching salts, an immense quantity of Glauber's salt, (sulphate of soda), is obtained from the residuum that remains after making chlorine gas in the common way: and as much of that salt is used medicinally;—it became an interesting question to ascertain, whether, in cases when the oxide of manganese contains oxide of copper, any portion of it would exist in the Glauber's salt obtained from the residuum after making chlorine gas. To determine this point was the design of this inquiry. I have not, however, limited myself to this question, but have connected with it, a few other considerations which may at least deserve the attention of manufacturers.

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* Smith, Cork, vol. ii. p 350.

† Smith, Kerry. p. 372.

Before I enter into a more particular description of the ore, which is the subject of this paper, and notice its composition; it may be proper to mention the circumstances under which I procured it. A friend of mine who is very extensively concerned in the manufacture of chloride of lime, lately received from a London house a number of casks of Manganese ore. Its exact locality was not given, but it was stated to be all Swedish ore, of the very best kind, of uniform quality, and of equal price. Two small average samples of the ore were sent to me, in order to determine the quantity of chlorine gas a given weight of each would yield under similar treatment. The slightest examination of the samples was quite sufficient to satisfy any one conversant with Manganese ores, that they differed materially in external characters, yet an experienced eye might be deceived in judging of their comparative value, for manufacturing purposes; both appeared to be of excellent quality, and quite free from foreign admixture. One sample was of a dark steel grey colour, massive, and in thin laminæ; lustre metallic. Fracture partly diverging radiated, and partly foliated. Brittle, soft, almost friable; easily reduced to an impalpable powder; heavy. The other sample, (which is the subject of the present communication), was of a dark, iron black colour, massive, lustre imperfect metallic. Fracture radiated, hard, not affected by the knife or file; striking fire with steel; difficultly frangible; heavy. Specific gravity, 5 157 anhydrous. Powder dark brown; became darker, and almost black, by being ignited. Not acted on by diluted or strong sulphuric or nitric acid, in the cold; and very slightly by muriatic acid, except by the assistance of heat, when it slowly dissolved with the evolution of chlorine gas. From preliminary experiments made on a very limited scale, I ascertained that this ore mainly consisted of oxide of manganese, and oxide of copper; together with a small portion of silex, and a trace of carbonate of barytes. Thus, a solution of the dry chloride in water, afforded with ferro-cyanate of potash, a white precipitate, which soon acquired a tint of peach-blossom red, without any blue; thus indicating the great predominance of manganese, and absence of iron. Ammonia being added, in excess, to a solution of the chloride, or to the pulverized ore, the fluid, after some hours, acquired a blue tint, which gradually became of a deeper colour. The presence of copper in the ore was also far more readily detected by the electro-chemical method I have recommended:* namely, by mixing a little of the ore in powder with a drop or two of diluted muriatic acid, on a slip of platina, and bringing a small slip of sheet zinc in contact both with the mixture and platina, when metallic copper was presently deposited on the platina. The turbidness of the muriatic solution of the ore was found to arise from the presence of a little silex; and the existence of an almost inappreciable quantity of carbonate of barytes was inferred from the evolution of some extremely small globules of gas, by cold diluted muriatic acid, on the ore, and the subsequent slight turbidness occasioned in the filtered chloride, by sulphate of soda.

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* Since writing the above, I have found in Haidinger's translation of "Moh's Mineralogy," a Manganese ore containing oxide of copper described under the name of "Cupreous Manganese ore." But this ore differs materially from the Swedish ore here noticed, as in hardness, specific gravity, fracture, locality, state of oxidation, and in containing a quantity of water.

The analysis of the ore was extremely simple, and it is scarcely necessary to give it in detail. I may, however, briefly remark, that, as the ore consisted almost entirely of oxide of manganese, with a little oxide of copper, the latter only being soluble in pure aqueous ammonia, I obtained very satisfactory results by putting 20 grains of the ore in extremely fine powder into a two ounce phial, nearly filled with strong aqueous ammonia, the contents were occasionally agitated; and, after about seven days, the whole of the oxide of copper being dissolved, the ammoniuret was collected, evaporated to dryness, decomposed by heat, and yielded 1 grain of peroxide of copper, equivalent to 0.9 grain of protoxide, and 19.1 grains of oxide of manganese. 20 grains of the ore digested for some time in pure muriatic acid, left a white residuum, which when washed, dried, and heated to redness, weighed 0.4 grain, and had the properties of silex. Hence, deducting from the 19.1 grains oxide manganese, 0.4 grain of silex, and a trace of carbonate barytes, which may be estimated at 0.1 grain.

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* Phil. Trans. Royal Society, 1831.

20 grains of the ore will be composed of		And 100 grains of
Oxide manganese	18.6	93.
Oxide copper	0.9	4.5
Silex	0.4	2.0
Trace of carbonate barytes, estimated at	0.1	0.5
	20.0	100.0

From the foregoing analysis, it appears that this manganese ore contains nearly 5 per cent. of oxide of copper, a quantity sufficiently large, I presume, to produce the most pernicious consequences, in the event of its entering into the composition of Glauber's salt, which might be made in processes where the ore might be employed.

To ascertain whether Glauber's salt, as commonly prepared, would be impregnated with oxide of copper, in cases when this oxide existed in manganese ores. I made chlorine gas, by mixing 500 grains of oxide of manganese with 25 grains of oxide of copper, adding the usual proportions of common salt, and diluted sulphuric acid: heat was applied till the chlorine ceased to come over. The residual salts being dissolved by warm water and filtered, afforded the first crop of crystals of Glauber's salt, in about 20 hours, and a second crop of similar crystals in about four days. In some days afterwards, a third crop was procured which appeared to be a mixture of Glauber's and common salt, but in none of the crystals could I, on examination, detect the slightest trace of copper, though all of them indicated the presence of both manganese and iron. The residual fluid was of a green colour, and by the electro-chemical method already referred to, a quantity of metallic copper, scarcely exceeding the two thousandth part of a grain could be readily detected, in a minute drop of it. Hence, it appears that Glauber's salt may be made from processes in which manganese ores, containing oxide of copper, are employed, without being impregnated with this oxide.

In my brief description of this ore, I have stated that it is "*difficultly frangible*," but these terms convey no adequate idea of the extreme difficulty of pulverizing it. It occurred to me that this inconvenience might be obviated, or at least diminished, by heating the ore to a dull red, and immersing it in water. On trial, this method succeeded well. A piece of the ore being thus heated, and put into cold water, the strong cohesion between its parts was destroyed, much of it separated into small fragments, which could be partially reduced to coarse powder between the fingers, and readily to a minute state of division in a wedgwood mortar. Whether this mode of pulverizing the ore would be economical, would obviously depend on the state of oxidation of the manganese. If the ore lost no oxygene at the temperature to which it was exposed, there was every reason to believe it would yield as much chlorine gas after being heated, as before. On making comparative trials, this was really found to be the case; and the chlorine was generated with more facility from the previously heated ore.—These results appeared to be confirmed by other experiments; thus on exposing the pulverized ore (in both states) in separate small green glass retorts to a full red heat, no oxygene gas was in either case evolved.

The manganese in this ore, appears to me to be in the state called by chemists *sesqui-oxide*, in which one equivalent of manganese is combined with one and half equivalent of oxygene: and my opinion is founded on the properties of the ore, the effects of reagents on it, the circumstance of its yielding no oxygene at a red heat; to which must be added the additional fact I ascertained, namely, that it affords, under similar circumstances, about the same quantity of chlorine, as the sesqui-oxide of manganese formed in the common process of making oxygene by exposing the peroxide to a red heat.

The copper in this ore seems to be in the state of red or sub-oxide. If a doubt could exist on this point, the aid of a powerful magnifying glass would have removed it; for on examining a small lump of the ore in this way, two mere specks of a carmine red substance was perceived on its surface. I attempted, (but in vain) to collect them for examination. Under all the circumstances, however, I shall venture to conclude that the red oxide of copper is disseminated, in minute particles, through this manganese ore.

This ore, in its properties, appears to agree very well with the manganese ore, first recognised as peculiar, by M. Haïdinger,* under the name of "*Braunite*," and by Dr. Thomson as "*Anhydrous Sesqui-oxide of Manganese*,"† and from the analysis of "*Braunite*" by the late Dr. Turner, it contains all the substances found in the ore I have examined, with the exception of the oxide of copper.

The value of manganese ores in the manufacture of chloride of lime, is, generally speaking, in proportion to the quantity of chlorine they will yield under similar circumstances; and this is again dependent on their state of oxidation and purity. In cases when the ores occur in the state of sesqui-oxides, they furnish little more than half as much chlorine, as when they exist as peroxides. The brief account herein given, of two species of manganese ore, illustrates those statements. The hard ore is the sesqui-oxide of manganese; the soft ore the peroxide. I found by comparative experiments, made under similar circumstances, that the quantity of chlorine gas yielded by the hard ore, was to that produced by the soft ore, as 1, to 1.81: and if we take into account the extreme difficulty of pulverizing the hard ore, and the facility of reducing the soft ore to powder; the latter must be regarded as about twice the value of the former, though before examination, the two ores were considered equal in this respect. Hence, it would seem, that the external characters of manganese ores, cannot with safety be relied upon, in determining their value for the purposes of manufacture.

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* Trans. Royal Society of Edinburgh, Vol. II.

† Thomson's Outlines of Mineralogy, Geology, &c., Vol. I.

ON THE SHELLY GRAVEL UNDERLYING DUNDALK.

(Read by Captain Portlock, R. E. May 14, 1834.)

The few observations I am about to make on the Bay of Dundalk may not, perhaps, be entirely devoid of interest. The bay, as may be observed on a map, is a very extensive inlet, bounded on the south by the projecting headland of Dunany Point, and on the north by the Promontory of Carlingford. The more retired portion of this extensive space is occupied by sands which, at low water, are laid bare for a considerable distance from the shore, the river keeping open a very winding passage. The sand is sufficiently adhesive to form masses, and to retain, if shaken in the hand, some degree of shape. Within this area which is still exposed to the sea, there is an extensive flat, which being strongly contrasted with the neighbouring mountains, necessarily attracts attention. On the sea edge of this flat, at Black Rock, about two miles from Dundalk, the greywacke strata are observed, their edges being much shattered, and their beds highly inclined. Their direction is nearly E. and W. and they may be supposed to continue beyond the tide-mark, at which their broken edges crop out, though at present covered with sand; whilst, in the opposite direction, they may be traced inland as a low ridge. In walking to this point I noticed a drain cut through the level and partly marshy space between the ridge and the Dundalk river, exhibiting, at some distance below the surface of the ground, a layer of shells, principally cockles (cardium edule), the same as those now occurring on the existing beach. Viewing Dunany Head as the boundary of the present beach, and the point of Greywacke Rocks I have mentioned as that of the former one, I was anxious to ascertain how far its littoral character extended, and desired my men to make excavations at some distance from the drain, so as to remove any chance of fallacy. The results are as follow,—using the words of Corporal Hemmings, who superintended the digging, and who examined also several gravel pits already opened :—

About 300 yards north of Mr. M'Callister's brewery is a gravel and sand pit in which the labourers say they have found shells, and certainly some do appear in the dry gravel that has been thrown up at a former period, but at a depth of ten feet, at which a layer of fine sand appeared similar to sea sand, and at a further depth of one foot four inches in this bed of sand, (water springing up profusely) I could find only a very few shells ; this spot is elevated above the neighbouring part 20 or 30 feet.

At an excavation at the west side of the avenue in Lord Roden's demesne, and near to the south gate, shells occur, though they are scarce, in a bed of yellow clay, at a depth of six feet below the surface, the clay is very soft, the shells very rotten, and there is plenty of water.

In Lord Roden's demesne, from 300 to 400 yards N.W. of the church, at a depth of 5 feet below the surface, shells are found of a description apparently different from those generally found nearer to the sea, but they are very scarce, and embedded in an apparently light sand, or rather mixture of sand and mud below the surface of the soil which is of a light description, and below the sand is a stratum generally known by the provincial term of Lake, being a soft mixture of sand and mud.

At an excavation made in a flat in Lord Roden's demesne, and about 300 yards south of the quarry, near the boundary of the townland of Farendreg, and about 150 or 200 yards north of the herd's house, shells were found at a depth of five or six feet, and continued to seven feet in soft mud, mixed with sand and plenty of water. This place is at least two miles from the present beach.

At an excavation made a little north of Castletown, and near the bed of the river, after a depth of about twelve inches of surface soil, a mixture of sand and clay occurs, for about two and a half feet, when a thin bed of fine gravel occurs, then alternate beds, or rather a mixture of sand and clay to a depth of 9 or 10 feet. No shells appear ; this is on the west side of the river.

At an excavation made on the east side of the river, and about a mile and a half from its mouth, near to its bank, a bed of fine sand is found (at a depth of five feet) not more than four or six inches thick; then a blue clay to 6 or 6½ feet. No shells appear. Townland Moorlands.

At an excavation made in Mr. M'Intosh's brick-yard in Moorland, 16 inches below the surface soil, the clay of which the bricks are made continue to a depth of three or four feet, a bed of sand then appears to a depth of nine feet, where water springs in such profusion as to prevent excavating any further. No shells appear.

At an excavation made at the bottom of a ditch by the road side, about half way between Dundalk and Castletown Toll-gate, shells appear in clay, at a depth of 6 feet, at 400 or 500 yards distance from the creek of sea, formed by the river at present.

In a gravel pit, sunk 100 yards west of the windmill, shells appear at a depth of 8 feet below the surface, this is nearly in an opposite direction to the last excavation (100 yards S. E. by E.) where they were found at a depth of 8 feet.

It is quite evident, therefore, both from the shells and the littoral character of the sands and gravels, that a considerable part of this now cultivated flat including the site of the town of Dundalk has been a sea beach at no very remote geological period. If I were to endeavour to explain or to reason on this change, I should observe, that the present surface is neither sand nor shells, but a bed or layer of clay, which indicates a very great alteration in the character of the deposits, even before the general surface had become totally dry—analogous in a remote degree with alternations of fresh and salt water strata in other classes of deposits. In this there is a river to yield mud, and if the Greywacke ridge be supposed to have been more entire when the first elevation took place, which removed the river beach from the action of the sea, the deposition within would have partaken of the river or muddy character; but when that ridge was broken and destroyed by the action of the sea, the water within would have been lowered, and the surface exposed, to become dry, and cultivated land, as it now is.

END OF PART III.—VOL. I.

JOURNAL
OF
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OF DUBLIN.

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1838.

is no evidence of organic life—and on still further investigation, we find rocks in which there are no traces of the modifying action either of drift, or of vitality, and hence, possessing that uniformity which, although not cotemporaneous in their appearance on the earth's surface, they might be expected to derive from the similarity of the causes, whether chemical or physical, which had co-operated in their production. In short, to use the words of Professor Phillips, "They never show any marks of arrangement, such as might arise from suspension or drifting, nor any such proofs of mechanical action, as worn grains of sand or pebbles of rock; but their composition is in the great mass, and in the nature of the constituent crystals, always analogous and frequently identical with the known effects of heat in the furnace of the chemist, or the subterranean laboratory of nature." (Geology, vol. 1, page 47.)

The next paper is one by Mr. Charles William Hamilton, on "The Limestone of the County of Wexford, and its geological position." In few countries, perhaps, is that great member of the geological series—the mountain or carboniferous limestone—so extensively developed as in Ireland; and it is therefore surprising, that so few attempts have there been made to establish a regular gradation in its successive beds. The difficulty, however, attending the investigation, and the caution required in carrying it forward may in part explain the defect, as it is surely here even more necessary than in the Silurian system (as remarked by Professor Phillips) to keep in view the permanency of the general, whilst considering the variations of partial causes, and to be constantly aware of the importance of the fact, that during so long a period as must have elapsed from the beginning to the end of this vast formation—the chemical conditions as shown by the continued calcareous deposition, experienced little change, although in organic life there appears to have been considerable variation. Some attempts, however, at subdivision have been made; and it has even been supposed that parts of the great limestone field of Ireland belonged to a more ancient system; but leaving aside conjectures, the peculiarities of the calp have long induced the belief that it occupied a distinct position as regarded the other portions of the limestone, and was, in fact, the lower member of the carboniferous system; whilst Mr. Phillips, Sir Philip Grey Egerton, and Mr. Griffith, have successfully shown the existence of a distinct upper member which they have considered identical with the scar limestone of England. The actual identity of the Calp with any portion of the English mountain limestone system has not yet been fully established, though some able geologists believe, that further examination will prove that such identity does exist. In conducting inquiries for this purpose in Ireland, it must be remembered, that the undulated surface of the limestone often lessens the force of evidence from apparent superposition, and that organic remains remain the chief, if not in many cases, the only clue to a solution of the question. Mr. Hamilton has proceeded on this principle, and having first traced the older rocks, such as the slates, and the sandstones and conglomerates of the old red sandstone, he notices a succession of organic remains in the beds of the mountain limestone of the rocks in the County of Wexford, arranged so as to establish three subdivisions of the limestone in that district: in the upper, the remains of zoophytes are abundant, but there are few mollusca; in the second there is an abundance of zoophytic remains, principally of two species, the syringopora ramulosa, and manon favosum, whilst in the lower portion there is an abundance of bivalves, though Mr. Hamilton does not consider any of them referable to the genus producta, so common in the scar limestones. Mr. Hamilton then compares and identifies by these fossils the limestones he had described with those of Malahide and St. Doolaghs, near Dublin, and is inclined, from the general evidence of the fossils and the occurrence of a new and very peculiar spirifer to detach this portion of the limestone, as a lower member, from the great mass of the mountain limestone. That Mr. Hamilton has, in this examination, strengthened the reasons for dividing the great mountain limestone into two divisions, I have no doubt; but as yet, I think the evidence insufficient for further subdivision, as the fossils stated are those which either occur in the mountain limestone of England, or are associated with those which do in other parts of Ireland.

The next paper I have to notice is on the Dingle district of the County of Kerry, and also by Mr. Hamilton. For this investigation, my friend wisely prepared himself by a visit to Caernarvonshire, and a study of its rocks; and I cannot too strongly recommend his example in that respect to other members of the Society.

The geology of this district, as illustrated by three distinct sections, shows a descending succession from the carboniferous or mountain limestone series on the north and east—to the great conglomerate and sandstone deposit of the old red sandstone, characterised here by the abundance of fragments of red jasper (often of large size) which the conglomerates contain, and then to a series of rocks which, as described by Mr. Hamilton, exhibit alternations of strata, of a schistose, arenaceous, and conglomerate structure—becoming in some cases slates—in others flag-stones, or conglomerates, and in one of the arenaceous beds exhibiting organic remains. Mr. Hamilton was unable to devote sufficient time for the full exploration of the fossils, but he found one trilobite, and an abundance of a bivalve, which he is inclined to think belongs to the genus orthis, as separated by Dalman from the terebratulæ. To all present, it is doubtless well known that the great and obscure geological region which, under the name of greywacke, so long received the bewildered inquirer into its dark and almost trackless recesses, and left him in hopeless despair, has by the labours and truly able researches of Professor Sedgewick and Mr. Murchison, been at length opened to the light, and made comparatively easy 'of access. It has been divided into two great systems, the Cumbrian and Silurian, which, although they may actually be parts of one still greater system, are marked by tolerably distinctive characters. Of the propriety of the terms used to designate them, at least of that of Silurian, there may however be some doubt. The objection to greywacke was its vagueness, much of which would have disappeared when it had been divided into upper and lower greywacke; and surely to a great portion of continental geologists unacquainted with the minute details of our ancient history and geography, the term Silurian will be equally unmeaning, if it be not even liable to misrepresentation.

In considering to which of the divisions the rocks described by Mr. Hamilton, as underlying the old red sandstone should be appropriated, there is some difficulty, from the paucity of organic remains as yet collected, but the presence of trilobites would rather induce me to place them in the Silurian. The fossiliferous slates of the South of Ireland have long been known. In the North I have pointed out in the Ordnance Memoir of the County of Derry, (vol. 1) the occurrence of a remarkable series of rocks of the Silurian system, principally schistose, and so rich in trilobites, that I have already identified the genera Calymene, Asaphus, Cryptolithus, Hemicrypturus, and the American genus Isotelus; and, I may add, found amongst the rarer and more strange species of other genera, the Calymene Blumenbachii. Here again also, we have in the West similar appearances, so that we cannot doubt, ere long, that these ancient systems will be as fully understood in Ireland, as they are in England. In the course of his paper, Mr. Hamilton also makes some valuable remarks on the cleavage or joints of slate rocks. I have long since pointed out to the Society the remarkable coincidence in direction of certain of the lines of cleavage in the greywacke schists of all parts of Ireland, and heir independence of the planes of stratification ; but this is now well understood to be the result of the indurating process to which such rocks have been subjected after their original deposition, the cleavage being a superinduced, not an original character. I trust, however, Mr. Hamilton will persevere in collecting data on this interesting subject. And further, I would hope, that he may return to the district he has so zealously examined, and by collecting further evidence, perfect the details of his inquiries. In doing so, he will remove any obscurity which still hangs over the extension of his reasonings to the great Kerry chain, and still further entitle himself to the approbation of the Society.

Leaving now the consideration of the older rocks, in which, though we trace forces similar to those now in action, we cannot avoid seeing an extent of effect very much exceeding any now exhibited, the subjects of our next papers gradually bring us to more recent periods. In a brief notice by myself, I have pointed out some interesting facts connected with a curious intercalation of trap (basalt) in the new red sandstone of Scrabo mountain in the County of Down. This spot has often been visited, and is well known as an outlyer of the great basaltic district of Antrim, being doubtless connected with it by trap dykes, some of which are either visible on the surface, or have been met with in sinking below it. The hill itself is capped with basalt, which is seen, as in the instance I have alluded to, alternating in thin layers with the sandstone. On looking at these, I was struck by the angular fracture and hardened texture of the sandstone immediately under the lower layer, and was induced to inquire as to the same effect being visible above the layer, but found that it was not. And again, on examination, it appeared that the sandstone was in a similar, though less degree hardened under, and not above the upper layer of trap, so that I am inclined to think there is evidence here of successive flows of basalt during the deposition of the sandstone of Scrabo.

Our active member, Mr. Hamilton, furnished the next paper on a tufaceous deposit, near Abbeyleix, in the Queen's County: a deposit of considerable extent, and furnishing, in connexion with that I have described in Mayo, proof of the continuity of this class of natural operations. The formation is carried back by Mr. Hamilton to a remote period, as he found portions of it in the walls of the old chapel of the rock of Cashel, the date of which is 1134. To this paper I appended a few remarks on the extent to which the well known solvent power of water, charged with carbonic acid, is exhibited—percolating through rocks in which lime is not perceptible to the common tests, it steals away the minute portions, and issues out in springs so charged with calcareous matter, that they deposit it in efflorescence on the herbage, or as in the cases described form extensive beds of tufaceous limestone. In this way, water is in constant action, as there is no deficiency of carbonic acid, being at once a destroying and renovating cause—sapping the one rock that it may deposit its lime in the form of another.

Of all geological phenomena, none have advanced more within the last few years towards a correct estimation of cause and effect, than those usually classed under the term diluvial. The opinions originally connected with that term were indeed the cause of the tardy progress, until then, of this branch of geological research, since the ready solution of every difficulty by an appeal to a great cataclysm, the amount and direction of which could not be correctly estimated, led observers to remain satisfied with a mere glance at that which required for its true solution a long and patient investigation of facts. This overstrained application of the diluvial theory has, however, given way to truth, and now in every sand hillock or elevated gravel bank, there is a subject of study leading to the enquiry how such deposits have been formed, whether by the slow and steady action of the sea when at higher levels, by the force of submarine currents, or by any other form of aqueous agency? No longer is every gravel bed considered of one date; some may have existed long before others; some may have been the consequence of fluviatile action—some of marine; one bed may have been covered over by another, and hence have succeeded it by an interval of time longer or shorter as the case may be. And hence it is evident that few phenomena are of more varied interest than those connected with this subject. In Scotland and England the study of transported detritus is now exciting the attention it deserves as a method of explaining some of the last changes which have taken place on the earth's surface. In Ireland also materials have been collecting for the same purpose. Mr. Griffiths has noticed in the south extensive detritic deposits, some portion of which is probably tertiary, the shells being partly of extinct species. The late Major Patrickson brought before our Society some elevated gravel beaches in the county of Down. I have myself added some instances, partly of my own and partly of Mr. Townsend's observation, of marine shells of recent species, elevated 100 to 200 feet and more above the sea, in the county of Sligo, and I have observed other similar deposits of still more interest in the county of Derry, where there are at least two, but probably several, distinct deposits of different ages, the results of very varied currents; and in the paper of Dr. Scouler, read before you this session, we have other and very striking instances in the neighbourhood of our city. At Howth, Dr. Scouler points out two deposits—one of clay without shells, and another of gravel with shells resting upon it. The shelly deposit he traces also at Bray, and finds pebbles of chalk, flint, &c. contained in it, so that the currents must have swept them a long distance and in a direction now traversed in part by elevated ground, as the nearest locality in Ireland for such debris is the county of Antrim. It is, however, necessary in considering how far these phenomena can be put in relation with the present configuration of the earth's surface, to bear in mind that the chalk range extends to the west of Lough Neagh, and occupies in Slieve Gallion elevated ground, and that it would be easier to imagine the debris of that region moved across the comparatively level country, and swept into the line of a subsequent north and south current, than to carry the debris of Antrim over the intervening county of Down.* The interest of Dr. Scouler's observation is much increased by the fact announced by Mr. Trimmer, that he has found fragments of the Irish chalk even in Wales. Dr. Scouler adds some remarks on the appearances afforded by several of the rivers and streams which traverse the district he has described, which shew that they are cutting channels in a detritus previously deposited in the original valleys, appearances, indeed, which may be traced in the beds of many, if not of all streams, as they are now necessarily forcing their way through the deposits left by waters which stood at a higher relative elevation. From the contemplation of those links in the operations of natural causes, which connect the past with the present, we are naturally led to consider the forces which are still exhibiting before us the full amount of their action, and we are here assisted by the ingenious paper of Mr. Mallett on "The Mechanism of the Motion of Glaciers." To all it will be familiar that the motive power of ice has long been called into play to account (though not satisfactorily) for the transport of some of the huge blocks of rock which are often found far removed from their native beds, and which would seem vast enough to defy the violence of any conceivable currents; but although in this general sense the explanation may be insufficient, there can be no doubt that within the range of ancient and modern glaciers, a great motive force has been exerted, and in consequence large masses of debris from the loftier rocks carried along by the ice in its progress and deposited in the lower grounds. To account therefore for the motion of these huge masses of ice and snow is the object of Mr. Mallett. At an early period it was suggested that should a glacier be formed at such an elevation, that the surface on which it rested was found below the point of constant congelation, there would be a radiation of heat from the earth to the lower surface of the glacier, and hence a melting of that surface. This was proved by examination to be the case, and as a fact, further established by the flowing of springs from the bottom of the glaciers; but, although the liquid condition of the under surface of the glacier was thus demonstrated, no advantage seems to have been taken of it as a means of explaining the progressive motion of such huge masses, which were supposed to be solely impelled forward (on the inclined planes on which they rested) by their great weight. This defect Mr. Mallett rectifies by shewing that during the more rapid period of thaw, a great accumulation of water may take place under the glacier, and thus serve to buoy it up and facilitate its movement under the influence of pressure, since it is evident that the water accumulating between the glacier and the inclined plane on which it rests, must raise it perpendicularly to that plane, whilst the pressure of its own weight will act perpendicularly to the horizon, the resultant being a movement of descent parallel to the inclined bed. Mr. Mallett explained further on the same principles—the great rifts or crevices in the ice, transverse to the valleys of the glaciers, and sometimes six hundred feet deep, the curvature of such crevices being convex downwards, the result of the greater precessional movement of the centre of the glacier due to the greater accumulation of water there than at the edges; and also the peculiar position of the moraines, or stoney debris, which are arranged in ridges and approximate by degrees towards the centre or axis of the glacier. I need not further allude to the minor phenomena connected with this paper, but I think it deserves a place in the Journal of this Society, as the result of a very careful and ingenious investigation of a very interesting phenomenon.

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* I have been informed of the occurrence of a chalk fossil in the bed of the Newry River.

In addition to the Geological papers which I have thus recapitulated, Dr. Beatty brought under the notice of the Society some specimens of fossils from the Himalaya mountains; and two very interesting mineralogical papers were also read, the first by Professor Davy on an ore of manganese containing about five per cent of copper, and the other by Professor Apjohn on a new species of alum, from South Africa. This last paper deserves especial notice, as it has an important bearing on that part of geology which is concerned in the enquiry how far a definite composition can or cannot be traced in rocks. To those members who devote attention to the chemical branch of our science, the advantages which have attended the introduction of a systematic notation, including formulæ, must be fully appreciated, since by such formulæ the principle of combination in various substances is brought distinctly before the eye; and it is easy to judge whether any one or more members of the compound could be replaced by others, having the same mutual relations. For instance, in the species of alum examined by Professor Apjohn, the alkali was found to be replaced by the prot-oxide of manganese, each having the same relation to oxygen; and in like manner, Professor Apjohn showed that an alum might be produced having no sulphuric acid, that acid being replaced by another body, the base of which was similarly related to oxygen. Somewhat in this manner Brochant and other chemists have classed many of the minerals which enter into the composition of rocks; the genus felspar for instance including many species differing in absolute composition, though conforming to the same chemical formula: and it requires no further comment to see that this is the right method of testing the definite composition both of minerals and of rocks, as it removes that confusion which from the frequent variation of the elements of bodies might appear to indicate a want of any fixed rule in their composition. Such then is the substance of our labours during the past session, and compared with those of preceding seasons, I think we may fairly say that they do not fall short in interest, and are calculated to advance the progress of geological science in Ireland.

I shall now, as briefly as possible, refer to some interesting points in the present state of Geological science. To us who now contemplate it, inviting the most profound philosophers to the investigation of those phenomena which are displayed in the disturbances of the earth's surface —in the elevation and disruption of its strata—in the degradation, removal, and re-consolidation of its component parts, or in the equally interesting spectacle of organic beings, entombed in the debris of former worlds, and now unknown as inhabitants of the earth, it may be difficult to conceive a period when no successive order of formations had been recognised in rocks, and yet such a period there was, and it by no means a distant one. By Lehman, the first great step was made, when in 1756 he introduced the division of primitive rocks, noticed their generally high inclination, and the superposition of the secondary or horizontal strata upon them. And the views of Werner are an expansion and a classification of his ideas. Reasoning indeed too widely from narrow premises, Werner supposed the mineral order of superposition to be more universal than it is, not sufficiently allowing for those variations which the introduction of mechanical causes must always produce. But it is not so much to his invention of the divisions, primitive, intermediate, and secondary; or to his admission of two operating causes, a chemical and a mechanical, that I now wish to allude; it is rather to the explanation of these phenomena which was given by the illustrious Hutton. By Lehman the primitive, or primary strata, including primary schists, were considered a portion of the original nucleus of the earth, which had undergone no change; by Werner they were considered the first deposits from the great primeval ocean which surrounded the world; but by Hutton all such stratified rocks were deemed to have resulted from the destruction of some portion of the original mass of the earth, removed by aqueous agency to a new position, there re-arranged and consolidated by internal heat. Now as no exception is here made in regard to those rocks we call primitive, such as gneiss and mica slate. It is evident, that the theory of Hutton embraces the theory which under the term metamorphic is supposed by many to be a new idea; it is even superior to it, as it explains on better principles the phenomena—the Huttonian theory distinctly stating that the various deposits formed at the bottom of the ocean are consolidated by fusion, the results being in proportion to their proximity to the source of heat, and in relation to the composition of the deposits themselves. On this theory, therefore, it is not necessary to suppose a clay slate first formed that it may be afterwards metamorphosed into a micaceous schist; the process is one. The supporting unstratified body, whether it be granite or other substance, may be in perfect fusion; the deposits nearest to it may also be so fused as to admit of a complete play of chemical affinities, and a consequent crystallization, while those more remote may merely be run together, or even simply softened; all these effects being necessarily modified by the nature of the substances acted upon, and by the time during which they were subjected to such action.

These remarks I have made to remove some erroneous impressions which I find have existed as to the tendency of my former observations on this subject. If fully carried out the principle they advocate—namely, that of Hutton, explains many effects which are now ascribed to very inadequate causes. Too often, indeed, do we hear the geologist ascribing to some insignificant dyke of porphyry or other igneous body the melting of masses of stony matter, which are in no proportionate relation to it; and yet how much more reasonable it would be to see in such veins or dykes the evidences of the common cause which had at once consolidated the superincumbent mass, and forced into its cracks those streams of more liquid matter; and in like manner, how frequently might be explained on these principles the intercalation of igneous rocks with hardened schists: the different composition of the one having given rise under igneous action to a true igneous rock, whilst the other became only a hardened schist, or should the heat have been insufficient, acquired only that rhomboidal or prismatic structure which is so frequent in all the older schists. That such a cause as internal heat exists, is now doubted by few. The evidence of warm springs which had retained their heat for ages, was adduced by Playfair; and the experiments of Cordier, Fox and others on the increase of heat in descending excavations, have done much to establish the fact. Most however of these experiments were open to some objections, excepting the more recent of Mr. Fox in which thermometers were imbedded in the rocks at various depths, and allowed full time to acquire the correct temperature. But even were some doubt to exist as to their results, those of M. de la Rive and Marcet are apparently such as must fully satisfy the mind. Taking advantage of an attempt to obtain water by sinking an artesian well near Geneva, those gentlemen determined to combine with it a further experiment on internal heat, and having procured a maximum register thermometer, upon the results of which they could depend, they enclosed it in a copper cylinder, so that it was secured from any chance of injury, and again in an outer cylinder, opening and closing at the bottom by a valve, in order to bring up the contents of the artesian pit at the locus of each experiment. The diameter of the pit or bore of the artesian well was four inches, and it was sunk to the depth of 700 feet, being 400 feet below the level of the lake of Geneva. The full details, it is not necessary here to give, but I may mention so much as will establish in your minds the fact the experiment was intended to establish. At 150 feet the thermometer stood at 9.2 of Reaumur, or at 52.7 of Fahrenheit. At 680 feet it gave 13.8 of Reaumur or 63 of Fahrenheit, having thus gained in 530 feet, an increase of 10.3 of Fahrenheit, or nearly 2° for each 100 feet of depth. I shall not at the present enter on the great question, as to the mode by which this internal heat may be accounted for; whether as a remnant of original heat, or of heat acquired in the passage of the earth through space, and therefore subject to variations, according as it may in infinite ages meet with hotter or cooler portions of that space, as the solar system with which it is connected shifts its positions; placing perhaps other of its planetary bodies into that fitting relation as to heat and other circumstances, which will enable them to support animated beings, when the earth now inhabited shall cease to be so. Nor shall I enter into a discussion on the present state of the interior of our planet, whether it may even yet be fluid, or whether by the great pressure it sustains a solid form is preserved notwithstanding the vast accumulation of heat to which it is subject; my object was rather to do away with the erroneous notions attached to a word, the ready use of which has doubtless facilitated to many the apparent solution of problems of extreme difficulty. It is easy to speak of the metamorphosis of one rock into another, but it is by no means so easy to prove the possibility of such a change. I trust, therefore, that my remarks have shown that the metamorphic theory is but another name for the Huttonian theory; and I may further add, that in its application it requires the caution of chemical examination. That all the older stratified rocks have undergone a certain extent of modification by heat, can scarcely be doubted; but it is difficult to conceive that such modification has proceeded to the extent, or been affected in the mode which has been supposed by Mr. Lyell and other advocates of the metamorphic theory. According to them gneiss and mica slate are granite rocks, which have undergone a total disintegration, and been reduced to a state similar to that of clay slate; and then by the action of heat reconstituted into a rock closely analogous to that from which it proceeded. Happy am I to see that the views I have always held on this subject are those adopted by Professor Phillips, in his recent treatise on geology; he supposes that gneiss and mica slate are indeed composed of the fragments of granite, but that they have not undergone any great change or removal before their consolidation, a view strongly supported by the fact that they are so generally in contact with granite rocks, and much easier understood than that which would suppose the alteration of a clay slate into such a body as gneiss. The operation of heat is manifest, but its extent is subject to much doubt and limitation. When indeed the speculative views of La Place and Herschel are combined with the phenomena of the earth itself, what a splendid chain of results is brought before us. In the nebulous matter scattered over space, we see indications of a gaseous state of existence, in which our planet may once have been. In the form of our earth, we see evidences of its fluidity, and in the protrusion of veins—the semi-fusion and hardening of rocks—the peculiar cleavage or structure superinduced upon them by heat after their original deposition—we have proofs that to a recent period, and indeed to the present hour, there yet remains a vast central source of internal heat. Nor is it only in this one enquiry that astronomy and physical research have lent their aid to the geologist. The theory of veins is every day acquiring a new interest and a more complete development, by the application of electro-magnetic science to its illustration; and in like manner thermo-electricity has been brought to bear on the phenomena of the earth. But it is not by the application of these laws of matter, as discovered and established on a small scale, to the solution of problems connected also with matter, but on a vastly larger scale, that geology can alone be assisted. The study even of the planetary bodies, remote as they are from us, is not without its use: when we look at them, we find that they exhibit conditions so different from those of our own, that the whole system of adapted creations, (that is of organic creations) must in them have been widely at variance with any of the analogies exhibited by those of our earth. Whilst, for instance, in Mercury we may suppose a degree of heat intolerable to us; in Saturn we may in like manner imagine a degree of cold equally intolerable.* It has indeed been quaintly said, "that if Saturn and Mercury possess inhabitants who have supplied themselves with thermometers, those of the mercurial inhabitants would be frozen under the most intense heat of our sun, whilst those of the Saturnians would be reduced to vapour by the hot chill of our Spitzbergen." But from our own minor planet or Satellite, even more instructing and surprising information may be obtained. The proximity of the moon and the various accidents to which in its relation to the earth it is exposed, have rendered it possible to prove (almost beyond doubt) that it possesses no ærial or vapourous atmosphere, and in this one condition it at once offers the most remarkable contrast to the earth, for it need not be here urged that all the organic structures of our globe have been formed in relation to the atmosphere, as containing the great principle of mundane life. Nor is it simply as respects this relation of organic beings to the air they breathe, that the moon is contrasted to the earth. If there be no atmosphere even of steam or vapour, it is not possible that there can be evaporable fluids, and hence, how different must any living beings be from us in whom all the processes of nutrition, assimilation, absorption, &c. are effected through the instrumentality of fluids. And are we to be satisfied with speculative reasonings on life?—far from it—the very aspect and external physical condition of the moon afford us lessons which we may safely apply to the investigation of our own planet. The telescope has shown that in a body sixty-one times smaller in bulk than our own, there are mountains to which our highest peaks are but insignificant hillocks. One of these projects as a huge protuberance at the S.E. quarter of its disc, and may be readily seen by a telescope of very moderate magnifying power.

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*The cold of the Planetary Spaces being greater than that of the Polar Regions.

It is not surprising that a body so small in mass, and hence possessing so low a coercive power from pressure on its central beds, should exhibit these gigantic proofs of elevation, and display in vast craters equally majestic evidences of volcanic action; but it may be well asked, why have not its towering mountains been wasted down like those of the earth? and here at once we find a solution in the absence of those fluids which in our earth are the great agents of destruction, and a proof, were it wanted, that even our mountains may at one time have been far more lofty monuments of expansive or elevating force than they now are. No longer, then, when we see evidences of ancient destruction in the oldest stratified rocks, need we feel a difficulty in bringing to our minds the pinnacles from which their aggregate particles have proceeded, since in the moon we see what might have been the state of our earth had it not possessed an atmosphere and fluids.

I shall now dismiss the consideration of that union of physical and geological research which so nobly characterizes the present epoch, and turn to one not less pregnant with interesting results, I mean the union of zoological, or rather natural science with geology. It is unnecessary that I should here go back to those days when the mind wavered in admitting the evidences of the senses, and considered the forms of organic beings which were brought before it as mere lusus naturæ, the results of a plastic power in nature; nor shall I do more than refer to the splendid discoveries of Cuvier—my object is rather to confine myself to the consideration of fossils as the test of successive geological ages. When the respected Dr. Smith brought brought forward his Strata identified by Fossils, the discovery came as a new and brilliant light, suddenly burst on geological science; but here, as in the theories of Werner, a good and most valuable rule was in an instant invested with a generality which in itself would imply a totally different state of the earth in most of its conditions than we now see before us. That to a certain extent such difference may be safely admitted is probable, for it can scarcely be doubted that in the earlier ages of destruction, a greater uniformity must have existed both in the mineral deposits as they had undergone fewer changes and less extensive removals, and in the temperature as the heat derived from the sun bore a less proportion to that derived from the earth, and therefore produced by its vacillations a less important effect on the general temperature. But still we should be cautious in discarding the analogies of nature, as they are now exhibited to us; and what, it may be asked, are they? Now, in order to show their bearing on fossil zoology, I may premise, that whilst some strata contain fossils peculiar to them, they also contain others which are common to many other strata. Is there anything equivalent to this in present nature? Perhaps there are no animals who possess a greater power of removing themselves from one region to another, should changing circumstances require it, than birds; and yet in them we find a very similar arrangement to that noticed as occurring in fossils. Let us for instance examine the example given by Temminck, in the third part of his manual, wherein he enumerates no less than 115 birds as common to Europe and Japan, and of these fifty-six at least are also common to Ireland. How remarkable indeed is it to find in this list four species of tits—the great tit-mouse, the cole-mouse, the common tit or blue bonnet, and the long-tailed tit-mouse; and even more so, the golden-crested wren, that most diminutive of our British birds, which abounds so particularly in Ireland. Nor is this the limit of universality, for I observe the common coot, fulica atra, which is also met with in Van Dieman's Land, and may therefore be considered as common to nearly, if not all the world. These are cases of identity; there are also others where the same general type is preserved, even in the most minute shades of colouring, without a positive identity. I have had before me the strix flammea of Ireland (or barn owl), and its representative in Van Dieman's Land, and in the two find the same principle as to the dots and other marking strictly preserved even to the black centres of the dots, although a little more intensity of shade is visible in one than in the other; and as another example of similarity in the mode of marking without a positive identity of colouring, the falco nisus, or sparrow-hawk, of Ireland and Van Dieman's Land, may be also cited, and there can be little doubt that some of Temminck's birds, marked in his list as varieties, are similarly circumstanced.

It appears, therefore, that in this class of the animal kingdom there are many species, and even genera, quite local in their distribution, whilst there are others which extend over the whole world, and form a part of almost every possible combination of organic beings. By travellers in general the well known are disregarded, and hence it is not easy to apply the same rule to all living creatures, but I would strongly recommend those who can devote sufficient attention to the subject, to collect information and to cull from travellers, as well as more scientific writers, materials for the comparison of the mollusca of different and distant kingdoms. We should then be better able to test the various combinations which are found in fossil zoology, and to determine how far they were compatible or incompatible with two or more conditions of the earth's surface, and hence how far their co-existence in the strata of distant places can be deemed a proof of simultaneous formation. But there is also another necessary enquiry before such determination can be safely formed. In nature we find that the rocky shore, the sandy beach, and the muddy bank have each their respective organic beings, adapted by structure to such varied conditions, and we are bound therefore to conclude that at all times similar genera must have been subjected to similar laws. We ought, therefore, in any assemblage of organic remains to ascertain whether the condition of the mineral surface at the time of their deposition were or were not consistent with the laws of their nature. This has been hinted at by Brongniart, in his history of trilobites, and has doubtless a much more powerful application to ordinary mollusca than to crustacea. In Ireland, as regards crustacea, the line at any one locality is strongly marked; for in the Silurian rocks of the north, though trilobites are in the extreme of abundance, they do not exhibit the species which at a very short distance from their geographical locality occurs in the mountain limestone, whilst that limestone has hitherto produced not one of the species found in the schists.

It is indeed so natural that the clay which gave rise to the slates should be tenanted by different beings to those which lived upon or about a coral reef, that when we find the same in both we must suppose that in one or the other their presence is accidental, and the result of some transporting cause. They are not in fact in the position in which they lived, and can only therefore approximate to the epoch of their existence. These observations, it must be clearly understood, are not intended to impugn the use of fossils in limited localities, where they are the very best of guides, nor to deny that under proper caution they can be often much more extensively applied, but they seem to me necessary to secure that patient investigation which can alone satisfactorily determine the great question of the extent and succession of organic beings, at various and distant portions of the earth's surface. Let those, therefore, who enter on such enquiries bear in mind, that in fossil zoology colour is absent, and hence a proof of identity in species when the form has accidentally varied is also wanting; and also a proof of difference of species when the forms are nearly alike; and further, that in comparing assemblages of organic beings at distant places, they must not only prove their identity of form—they must show that the animals could have existed under such varying conditions. Were this more frequently done, it is possible that many of those identifications of strata resting on fossils, but which are entirely opposed to the mineral conditions associated with them, would be abandoned, and taken, not as the evidence of co existence of those strata, but rather as evidence that the original stratum had totally passed away, and left these relics of its existence in a newer formation.

Gentlemen, I have thus placed before you a few hints, which I think may be useful as regards a theory now so readily applied to all changes of the mineral structure of the earth, and also as regards that which regulates the history of its ancient inhabitants, and applies that history to the elucidation of the successive epochs of the world's creation and changes. However we may view fossil zoology as a guide to time, we must consider it of infinite value as a guide to a true knowledge of nature, and amongst the most remarkable truths it developes is this, that in the earliest ages of the earth's history the same plan of creation is manifest, and the same adaptation to elements which, whilst they work such wonderful effects on our planet, do not seem to hold the same place in the systems of other worlds.

Before I close, let me advert, though I may do it with some pain to myself and to others, to the losses which this Society has experienced since our last anniversary. In Dr. West, a very laborious and active geographical antiquary was removed from us and from society, and we were thus deprived of many useful additions to our stock of knowledge, which he doubtless would have brought forward. But, if we experienced in him a loss, what words can describe that which came upon us, when he who had presided over our first meeting, and as it were called us into existence, was snatched away. I will not attempt to dwell on such a painful subject; the character of Dr. Lloyd as a man of science has been already recorded in the testimony of every learned body in our city; and to his private worth, we can only echo, and humbly echo that affectionate tribute of feeling, which has burst from the heart of every one who had the honour of his acquaintance. Let us reflect on his successful career in science, and connecting his name, as we do, with the establishment of our Society, let us endeavour to carry with us a portion of that honourable fame which must ever be attached to the memory of one so exalted in the scale of intellectual eminence.

ACCOUNT OF CERTAIN ELEVATED HILLS OF GRAVEL, CONTAINING MARINE SHELLS WHICH OCCUR IN THE COUNTY OF DUBLIN.

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THE object of the present communication is to give a brief account of a series of phenomena which, although of sufficiently frequent occurrence in almost every country, have only recently been observed in Ireland. The only writer I am acquainted with who has noticed the accumulations of gravel and marl, which are so frequent in the county of Dublin, is Mr. Weaver; but that careful and correct observer has no where alluded to the most interesting circumstance connected with their history, viz. the existence of marine shells, which if rare in some situations are very abundant in others.

Before entering on the more immediate subject of this paper, it will be of advantage to give a short outline of the geological structure of the district in which the conchiferous beds have been observed. The country around the Bay of Dublin, consists partly of primary and partly of secondary rocks, the more elevated region consisting of the former, while the latter occupy a lower position. Granite is observed only on the south side of the Bay, constituting the sole rock in the vicinity of Killiney, whence the granite axis of the Wicklow Mountains takes its commencement, and from thence continues its course in a southerly direction for upwards of sixty miles. It is also of importance to remark, that the Wicklow and Dublin granite, differs considerably in its mineral characters from that of the northern range of the Downshire mountains. The Dublin granite is distinguished by the whiteness of its felspar and the complete absence of hornblende, even as an accidental ingredient. The granite of the Mourne mountains on the other hand, contains abundance of hornblende, and the felspar is of a fresh red colour.. These circumstances afford a valuable criterion, by which we may distinguish the travelled portions of granite from those which are merely the detritus of the adjacent rocks. The granite axis of the Dublin mountains is flanked on both sides by strata of micaceous schist, which, however, no where within this district attains any considerable thickness. The micaceous schist has usually a finely laminated structure, and frequently contains but little quartz, and passes into a fine compound of argillaceous schist and mica; and when in contact with the granite, the plates of mica are replaced by laminæ of talcite. This schistose rock is succeeded on both sides of the granite axis by strata of argillaceous schist, which often assumes the appearance of metamorphic beds of primary greenstone and porphyry. On the western side of the Dublin Mountains the argillaceous schist graduates into greywacke, which is followed near Lyons by an extremely ferruginous sandstone conglomerate. In addition to the rocks already mentioned, if we return to the eastern side of the granite range we find several conical mountains, namely, the greater and lesser Sugarloaf, Shank-hill, and the promontory of Bray-head, which consist almost entirely of primary quartz rock.

On the north side of the Bay of Dublin, the only primary rocks which require notice, are those which constitute the Hill of Howth and Lambay Island; Howth consists chiefly of numerous alternations of primary quartz and schists, which, although of exceedingly diversified characters, may be comprised under the denomination of argillaceous schists: Lambay Island is composed of stratified and metamorphic porphyry, consisting of an argillaceous basis, with crystals of red felspar, and containing a few veins of jasper and chalcedony. At the northern extremity of the island, there is a stratum of ferruginous sandstone conglomerate, and the same rock also occurs on the adjoining mainland, constituting a considerable portion of the peninsula of Portrane. Porphyry similar to that of Lambay is found also in situ on the shore at Portrane.

The only secondary rock to be noticed, is the carboniferous limestone, which every where occupies a lower level than any of the preceding rocks, occurring under the form of calp, or impure argillaceous limestone, in the immediate vicinity of Dublin, and in that state containing but few organic remains; in other localities it assumes its usual characters. The limestone immediately follows the granite at Black-rock, near Dublin; near Howth it succeeds the primary quartz and a bed of dolomite occurs at this junction; in other places it is in contact with the ferruginous conglomerate belonging to the old red sandstone which has been already noticed.

The shelly calcareous gravel and elevated beaches which occur in this limited district, present such a variety of character in different situations, that it is difficult to give any general description which will apply to every case, and which would not suffer by the omission of details, so as to exhibit the appearances in a very defective light. Near the harbour of Howth, and to the south of Bray-head, they exhibit the appearance of perpendicular cliffs, varying in height from 80 to 200 feet, and consisting of irregularly stratified beds of fine sand and coarse gravel. In other instances, similar cliffs occur at a distance of several miles from the present sea; in some cases they form low rounded hills, in others they have filled up hollows and depressions in the soil. There is also considerable variety in the disposition of the materials which constitute these accumulations; in some the stratification is extremely conspicuous, while in others we perceive no vestiges of gradual deposition.

The vicinity of Howth harbour affords a very good example of elevated shelly gravel; and also the interesting fact of two accumulations, of what has been called diluvium, perfectly distinct in their age and characters. On the south side of the promontory of Howth, where limestone approaches the primary quartz, a depression occurs between the two formations, which is filled up by an exceedingly tenacious clay of a deep red colour, and extremely ferruginous. This clay extends across the peninsula, and is visible in many places filling up the fissures in the limestone. This argillaceous bed exhibits no traces of stratification, nor does it contain any transported fragments whatever; it, however, abounds in metallic substances, such as oxide of iron in nodules of considerable size, iron pyrites and oxide of manganese, which last is extracted for economical purposes. This local deposition is not to be confounded with the beds of marl or of shelly gravel, which are not only of a different nature, as is proved by the difference of mineral contents in the two deposits, but of a more recent epoch as is proved by their superposition.

The shelly gravel is an extensive accumulation nearly half a mile in length, but separated into two portions by a hollow in which the village of Howth is situated. The highest portion of the mass is about 80 feet above the level of the sea; it rests indifferently on quartz rock, carboniferous limestone, and alluvial clay. The accumulation consists of alternating beds of fine sand and a coarser gravel, composed chiefly of fragments of limestone, differing in no respect from the ordinary limestone of the surrounding country. These calcareous pebbles with fragments of argillaceous schist, are not uncommon: granite also occurs, although sparingly; and what is remarkable, fragments of quartz are rare, although the beds are partly deposited on that rock which also rises several hundred feet above them. But the most remarkable, though least frequent ingredient in these beds of gravel are fragments of flint and white limestone, (chalk) which do not occur in situ nearer than the county of Antrim, which is about one hundred miles to the north of Howth. The occurrence of flints in this and other localities to be mentioned afterwards, had often been remarked, but their origin was not satisfactorily made out, and till my friend, Mr. Trimmer, pointed out to me the fragments of chalk which had escaped my notice, and the observation once made, was soon verified in other situations.* The stratification is very distinct, consisting frequently of thin beds of fine sand and gravel, the strata, however, are not continuous for any great length but thin out and disappear, in this respect resembling the beaches of the present shore. Some of the beds of fine sand are of considerable depth, and the lower portion of the beds graduates into a marly clay. The shells which we found in these strata were seldom perfect, but broken portions of bivalves and univalves are not uncommon, and they occur at every degree of altitude throughout the deposit. All the shells whose species could be ascertained, belong to races at present existing in the Bay of Dublin. The following list is scanty, but its accuracy may be relied on, as I have excluded from it all inferences drawn from imperfect portions which could afford no decided result.

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* Since writing this sentence I have received an interesting communication from Mr. Trimmer, in which he states, that he has found the Antrim chalk in Wales. "I have just found in cliffs of bluish clay, in the horn of Caernarvonshire, fragments of the white chalk of Antrim, precisely similar to those we found near Bray-head; they likewise contain a good deal of limestone which I think is derived from the calp.

Turritella terebra.
Turbo littoreus.
Nerita littoralis.

Buccinum undatum.
Cardium edule.
Cyprina islandica.
Pecten varius.

If from Howth we cross the Bay of Dublin, and examine the south side of the promontory of Bray-head, we shall find still more extensive shelly beds. The elevated beds extend along the shore for upwards of a mile; at their northern extremity they exhibit a vertical section of about two hundred feet in depth, but it gradually diminishes in height as we advance to the south, till it finally sinks to the level of the present shore. In this accumulation of gravel, and sand, and marl, the stratification, is of the same irregular nature as at Howth, only the strata are of much greater extent and thickness. These various beds of transported matter may, however, be classed under three divisions: the lower portion consists of a mass of clay or marl; the middle portion consists of numerous beds of sand and calcareous gravel, containing shells and transported stones of various kinds; and the third, or upper part, consists of angular fragments of quartz rock and granite, obviously the produce of the adjacent high land. The middle portion is the most interesting, for in it we find abundance of shells of the same species as those which occur at the hill of Howth. Of these shells, the hinges of the Cyprina islandica are the most abundant, entire specimens of Turritella terebra are not rare, and the Dentalium entalis is occasionally found. The principle ingredient in the gravel consists of fragments of limestone, although the nearest locality in which that rock occurs in situ, is separated from the shores of Bray by the whole breadth of the Dublin mountains. The limestone fragments are of moderate size, and are very imperfectly rounded, proving that they have not been exposed to any powerful or long continued attrition. We cannot have a stronger evidence of this fact, than by comparing the limestone fragments which occur in situ in the beds, with those which have fallen down, and have been exposed to the action of the tides. In the first case the forms are extremely irregular, while in the latter they are flat, smooth, and discoid, or perfectly elliptical. But it is very remarkable, that while from the form of the fragments of limestone we should infer a very moderate amount of transporting force, we find in the very same beds portions of rock which do not occur in situ within 100 miles of Bray-head. These travelled stones consist of fragments of chalcedony flints and chalk, similar to those which occur in the county of Antrim along with granite and ferruginous conglomerate from other localities. Of these ingredients the granite, or rather the syenite, is recognised by its hornblende and flesh-coloured felspar to be the same as that which is found in the Mourne mountains, sixty miles distant from Bray. The ferruginous sandstone conglomerate is found in two less remote situations in Lambay island to the north, or at the hill of Lyons to the west, but in either case its transportation is very difficult to explain. If the conglomerate fragments came from Lambay, they must have travelled across the Bay of Dublin, if from Lyons, then they must have ascended the intervening Dublin mountains. The flints agates chalcedony and chalk, are only associated together in the northern extremity of Ireland, and singular as their existence in the detritus of Bray-head may appear, it is a fact, concerning which no doubt can be entertained, as fragments of agate and chalcedony are sometimes picked up on the shore by the curious, and cut into ornaments. Barton, in his history of Lough Neagh, published in 1751, mentions, that these pebbles which are found along the shore from Dublin bay, as far south as the town of Wicklow, were in his time much in request as gems; he states that a party, of which he was a member, took up their residence near the bay for the purpose of collecting them, and tells us that great quantities were collected in the vicinity of the town of Wicklow. The same localities still retain the same reputation. The association of chalk and altered flints with these pebbles, affords a sufficient indication of their original position.

Besides these deposits of Howth and Bray, which may be viewed as the remains of ancient beaches, similar deposits are extremely abundant in the interior of the country. The Liffy, the Dodder, and other streams, which empty themselves into the Bay of Dublin, take their origin in the adjacent mountains, and are formed by the confluence of numerous rivulets, which flow through vallies excavated in the primary strata, and occupying a higher level than the limestone strata of the surrounding country. If we ascend to the sources of these mountain streams, we find that the vallies have been blocked up by accumulations, not of primary rocks, but by beds of limestone gravel; and also, that to a certain extent, these vallies have been reopened by the transporting action of their respective streams. The valley of Glenismaule, in which a branch of the Dodder takes its rise, affords a very good example of these phenomena. It is bounded on both sides by perpendicular cliffs of calcareous gravel of about one hundred feet in thickness, and probably two hundred feet above the level of the sea, and this deposit, like that of Howth, consists of discontinuous and irregular beds of sand and calcareous pebbles. It is also deserving of notice, that the bed of gravel in this valley occupies a higher elevation than any of the limestone strata at the immediate vicinity. Here also, as in many other places, the solubility of the calcareous matter has often united large masses of the gravel into a limestone conglomerate, and cemented portions, weighing several tons, are occasionally detached from the cliffs. In other places, extensive deposits of calcareous tufa are formed; and in others, we have the phenomenon of calcareous springs issuing from a primary district. Fragments of shells of the species already mentioned are not uncommon, and in one instance a specimen of limestone, perforated by the Lymnorea terebrans was found—specimens of flint and chalcedony are not very rare in this valley. The whole of the country through which the Dodder flows is strewed over with fragments of limestone, mixed with those of primary rocks. These fragments of limestone, however, are not derived from the present limestone strata over which the river flows during a part of its course, for they are every where above such strata, but they are the transported materials of the shelly gravel which the streams have carried before them, while reopening the valleys through which they flow. This twice transported limestone alluvium extends from the valley of Glenismaule to the Bay of Dublin, a distance of about seven miles.

Besides the accumulations already mentioned, others of a precisely similar composition exist in a great variety of situations, forming low rounded hills, or filling up cavities in the soil, but into the history of these deposits it is unnecessary to enter. Before concluding this part of the subject, it may be proper to mention that these phenomena are by no means local or confined to the neighbourhood of Dublin; similar deposits appear to occur over every part of Ireland. In the north of

Ireland, near Ballycastle, I have observed the vallies filled up by transported matter, which, if similar to those of Glenismaule, with respect to the arrangement of the materials, differ much as to the materials themselves. Near Ballycastle, the beds are composed chiefly of chalk, flints, and trap, and in short, of portions of adjacent rocks, proving that in this instance, as in those around Dublin, the pebbles had not been exposed to any lengthened transport. The *drumlins*, as they are called in the north of Ireland, are another example of similar phenomena. These drumlins are very common in many parts of the country, and a very fine example of their nature occurs between Belfast and Lisburn: we have a long course of rounded hills of an elliptical form, and although not continuous, yet the range holds a flexuous course for a distance of many miles. These hills consist of irregular strata of sand, and fragments of different rocks, chiefly of those of same kind as exist in situ in the country, that is, chalk, flints, and traps; they are not completely rounded, with the exception of the flints, an exception which proves nothing; and if the trap fragments are often rounded, it is not from attrition, but from the spheroidal form, into which such rocks are so often resolved by decomposition. The stratified nature of these deposits appears to exclude the idea of their having been produced by the action of any temporary but transient current.

It remains to be stated that with one exception, no remains of any mammiferous animal has been hitherto detected in these recent deposits. The exception alluded to is the occurrence of the fossil elk in gravel at Enniskerry, near Dublin. The circumstances are thus stated by Dr. Hart:—" In the autumn " of 1828, while some workmen were employed in making " preparations for planting the southern aspect of a hill of " loam sand, close to Enniskerry, they dug up several bones " belonging to the fossil deer, which lay buried in the loam at " depth of three or four feet below the surface, and at an ele" vation of forty feet above the level of the bed of the river, " which runs at the base of this hill." The bones are preserved in the Museum of the Dubiin Society, and are, as Dr. Hart has observed, much more imperfectly preserved than those which occur in marl; they are dry, soft, and friable, from having been but imperfectly protected. In this instance if the bones were found actually in the gravel, we have an example of the oldest formation in which the remains of the extinct elk have been found in Ireland, for these beds of calcareous gravel are antecedent to the beds of marl in which the relics of the elk usually occur.

Although the phenomena already detailed may admit of different explanations, according to the theoretic prepossessions of different geologists. still there are several circumstances which will probably be assented to by all who admit the accuracy of the facts.

1st.—It seems obvious from the preceding details, that the coast around the bay of Dublin has been elevated at a comparatively recent geological epoch, and that the amount of this elevation has varied at different places.

2nd.—That the vallies around the Bay of Dublin, were at a former period under water; when they were filled up by calcareous gravel, &c. and that they have been subsequently elevated; and since that period the streams have been occupied in reopening the obliterated vallies, and spreading their contents over lower levels, where it now forms an alluvium derived from a pre-existing one.

It is difficult to speculate on the much-disputed subject of diluvial formations, but the following explanation appears to account for the phenomena described. The accumulations of transported matter which have been detached are usually and imperfectly stratified, proving that they have been deposited at intervals under the influence of conflicting currents, and the imperfectly rounded nature of the materials, proves that they have not been transported from very remote localities; but on the other hand, the existence of fragments of syenite with chalk and flints, would appear to indicate the action of a powerful current from the north. It appears also improbable, that the actual strata of carboniferous limestone should have afforded the abundance of limestone which exists in these elevated beds; for in every instance, the accumulations of transported matter occupy a greater elevation than any limestone beds in the vicinity. If we imagine that while the shelly beds were forming, the limestone occupied a high position, and that subsequently it has either subsided, or the adjacent country has been raised above it, we ought still to have evidence of the enormous dislocations which such complicated motions must have produced, but no such proof is to be found. There is another supposition which is familiar to geologists, and which, I think, will afford a satisfactory solution of all difficulties. The submergence of the land must be admitted upon any hypothesis, and if we admit that when this was the case, a tract of land existed in the place now occupied by the Irish sea, we have in its disintegration a source whence all these different rocks which occur in the transported matters might be obtained.

It is also very probable, that if the opinion here advanced be correct, that the elevation of the coast was gradual and unequal in amount, and the different altitudes which the shelly gravel attains in different situations, affords a confirmation of this view of the subject. We have seen that the greatest height at which marine shells occur at Howth, is from eighty to ninety feet, at Bray-head at an elevation of at least one hundred and fifty, while at Glenismaule they were still higher. Elevations to such an amount must, no doubt, have been attended by the exertion of considerable force, and of this, I think, some indications are still to be found. At Howth where in one place a satisfactory view of the lowest beds of transported matter can be obtained, we find the limestone of the rock on which they rest has been greatly shattered, and sharp points of it project into the alluvium, and loose angular fragments of the limestone are to be seen, which have merely been detached from their parent rock, but have suffered no transportation. Had these blocks been detached previous to the deposition of the transported matter, we ought to expect that their angles would have been rounded, and even that they would have been perforated by boring shells; of this we have obtained no evidence. Near Bray we observe similar detached fragments, but they are not of limestone but quartz rock. There is also another very curious phenomenon, which I think may be associated with the preceding one. Besides the vallies, whose streams discharge themselves into the Bay of Dublin, and which we have seen, have all been formerly blocked up by transported matter, there is another set of vallies or more correctly ravines, which have a general easterly and westerly direction, and are consequently nearly at right angles to the vallies containing transported matter, and these ravines are all destitute of any beds of gravel or detritus, carried from a distance. The vallies, or gaps, which possess this negative character are the Scalp, the Dargle, and the Glen of the Downs; the first cuts across both the granite axis and the strata of micaceous schist which recline against it; the second is nearly parallel to the first, and the third has cut through strata of quartz rock. All these ravines contain vast detached blocks of the adjacent rocks, granite in the first, and quartz in the second. Now it appears probable, that the formation of these ravines was subsequent to the deposition of the shelly gravel; for had they existed along with the vallies containing transported matter, it is difficult to conceive how they should now be so thoroughly destitute of all vestiges of it, especially when it is remembered, that none of these ravines ever possessed any stream which could carry off their contents. As many of the shelly gravels occupy a higher level than these valleys, it is inconceivable if both orders of vallies were contemporary, and both equally under the water, as must have been the case, upon what principle of selection one set were the receptacles of transported matter while the others escaped? It therefore appears probable, that the ravines were of a later origin, and are with the shattered blocks which are still in situ, the indications of the nature of that force which has elevated the shelly beds to their actual position.

AN OUTLINE OF THE GEOLOGY OF PART OF THE COUNTY OF KERRY.

BY CHARLES WM. HAMILTON, ESQ., M.R.I.A., F.G.S. &C.

The most westerly and mountainous part of the County of Kerry, consists of two distinct portions—the baronies of Iveragh and Dunkerron, which portion is bounded on the south by the Kenmare river, on the east by the Lakes of Killarney, and on the north by Dingle bay, and the long and narrow peninsula of Dingle comprising the barony of Corkaguiney, this portion extends about thirty-five miles westerly from Tralee.

What I propose to lay before the Society at present are three sections taken across the Dingle district, the most easterly of which I have prolonged on the north to Ballybunian, and on the south to Dunkerron on the Kenmare river.

It is, indeed, a very imperfect outline of the geology of this district that I have to present to you, but I give it only as a rough sketch, and in the hope that where I have as yet failed, in restoring to imagination the primitive order of those rocks which lie in such apparently inextricable confusion, yet this sketch may serve as a groundwork, upon which I myself, or some other member of your Society, may found other and more minute observations, leading to our becoming at length more intimately acquainted with this very interesting portion of our own country. Before I proceed to the details of the sections, I will attempt to give some description of the outward appearance of the country:—Between Tralee and Castlemaine, the mountain of Cahirconre rises to a height of 2784 feet; on the east it declines gradually to the level of the country surrounding Castle-island, and on the west terminates abruptly in high steeps, rising from a valley which traverses from Inch to Ballygobbin, and disconnects this mountain from the Dingle range, which latter extends in a westerly direction, attaining its greatest height in Benoskea, Connor-hill, and Brandon, which forms the highest summit, and is 3112 feet above the sea ; the minor features are, a chain of low hills, extending from Inch along the shore to near the town of Dingle, and a line of headlands running from Sybil-head to Brandon, rising quite precipitously from the sea, to a height of from six to eight hundred feet, and falling off on the east to a sandy level, which separates them from the central chain. The belt along the coast, which is inhabited, is so narrow, that the general effect is, that of a mass of unwooded and abrupt mountains stretching into the Atlantic ; the variety and beauty of the wild flowers which adorn their sides have been long familiar to our native botanists, Mr. Mackay and Mr. Taylor ; but if the lovers of the picturesque beauties of nature knew but half the glorious scenery that is to be found among them, this extreme point of western Europe would be more frequently visited and acknowledged as equal to any of the favourite haunts of tourists. If we walk along the shores we see mural precipices of 800 feet in height, opposed as barriers to the vast Atlantic, whose waters, in their calmest mood, break against the rocks with a violence which conveys an idea of the power and strength of the ocean, hardly appreciable by those who are acquainted only with the channel seas. If we ascend the mountains we are charmed with the wildness of their rocky defiles, the richness of their flowery vegetation, exceeding anything I have elsewhere seen, and the depth at which the lakes are embosomed in the midst of them. The precipices over Connor lake rise to about 1500 feet above its surface ; from the summit a panorama is exhibited, of which I know no equal. To the north, the broad mouth of the Shannon, flanked by Kerry and Loop heads, and the distant peaks of the Bunabola or Cunnemara mountains ; to the west, the spacious Atlantic with the Blasket islands, thrown out as it were a breakwater against the violence of its surges ; to the south, the tumultuous mass of the Iveragh mountains from the serrated Reeks to the island of Valentia, and in the far distance Hungry-hill, and the southern headlands of Cork and Kerry.

The first section which I made (plate 1 sect. 1) extends from the signal station at the mouth of the harbour across Connor and Brandon hills to Brandon-head ; the direction gradually increases its deviation from a line E. and W. at Dingle harbour to a line 27° N. of E. at Brandon-head, the dip is, with the single exception of Brandon-head, invariably to the south. I shall begin at the signal station and follow the descending order: the first rock is a coarse siliceous conglomerate, having an inclination of 80° and more sandy than the inferior strata, of a reddish hue, and with horizontal joints, which are generally filled with quartz; under this lies a succession of alternating beds of red slates, coarse grey siliceous flags, and very coarse conglomerates; the slates occasionally contain pebbles, and the coarse flags contain large fragments of fine red slate; the beds vary from three feet to a few inches in thickness, and these frequent alternations extend to inside the harbour mouth, giving a thickness of formation of about 1700 feet. Here we meet with that great mass, varying so little in lithological character and comprising all the hills between Dingle and Brandon-head, Eagle mountain, and all the inland hills to the west, and a mile or so east of this section, of which I can speak from actual observation. That the remainder of the range as far as Cahirconrè, is composed of this same rock, may be fairly inferred from the fact, that I have found no specimen of a different nature anywhere on the base of these hills, or in the water-courses which descend from their summits. The rock may be described as a coarse siliceous conglomerate, containing rolled pebbles of quartz, feldspar, and of itself, and angular fragments of fine pink-coloured slate; it is extremely hard, and of a dark grey colour. At Connor-hill the direction is 17° N. of E. and the rock is divided by two sets of joints, one dipping at an angle of 50°, and another at 80° to the south. Here the rock is of so homogenous a character, that I could not satisfy myself as to which of the systems belonged to the true cleavage, and which to stratification; and I remained in doubt until a subsequent examination of Brandon-hill, and the magnificent escarpment exposed on the side of the Letteragh lakes, where the coarse beds alternate with beds of a finer composition, left no doubt upon my mind that that system which in Connor-hill dips 50°, and in Brandon 40° to the south, is in the true plane of stratification.

I may here mention some conditions which I have observed, to attach invariably to the joints coincident with the stratification, and those which we designate by the term cleavage.

The joints of cleavage are more frequent; they divide the mass into thinner portions; they are more persistent; the various causes to which the alterations of rocks are attributed appear to have more easily obliterated the traces of stratification than those of cleavage.

The joints of cleavage have usually an angle of dip, varying from between 80° and 90°, and in any one instance they traverse the mass at the same angle, however contorted may be the strata of which that mass is composed. Thus in the annexed sketch, (Diagram A,) taken from a natural section in the County of Cork, the straight lines represent the cleavage, the curved lines the stratification, and thus we have in the space of a few yards the plane of cleavage presenting almost every possible angle to the plane of stratification.

It appears to me that, wherever the dip of the strata approaches that limit within which the dip of the cleavage ranges, the two sets of joints coincide. I shall not now enter into any detail respecting the other joints, as I hope to be able to make the remarkable coincidence in the jointage of all the slates of all ages that I have had an opportunity of observing in this country and Caernarvonshire, a subject of future communication to your Society.

The mountain of Faughagh, between Brandon and Brandon-head, presents no material change from the character of the rock already described. In the section along the coast from Cloghane to Brandon-head, the coarse flags become more compact and assume a redder hue. To the north of Brandon-bay I found a conglomerate dipping into the sea to the north, except upon the summit of the point of Brandon-head, where it overlaps that eminence, dipping again with the underlying rocks to the south, it is coarse and red, containing pebbles principally of quartz, but with a good sprinkling of red jasper, and the coarser of the compact slates, it does not appear to contain the fine pink slate, so general in the grey underlying rock. The neighbouring headlands are composed of this same conglomerate, dipping from 20° to 30° to 27° W. of N.; it has all the external character of the conglomerate of the Gaulty mountains. I may here observe, that the disposition of the joints in the old red sandstone of England, and the conglomerates of the Gaulty mountains, is such as to produce in the rock a division into cubical masses, whereas the other arenaceous rocks and conglomerates, both older and newer than these affect upon the large scale a rhomboidal fracture.

The next section which I made was from Sybil-head to Dunmore-head, (Plate 1, sec. 2,) this is a perfectly natural section, as the rocks are exposed the whole way along the coast, except in one short space at the bottom of Ferriter's cove, a distance of about six British miles. The strata dip all the same way, *i. e.* to the south with an angle of from 40° to 80°.

I shall begin as before with the southern extremity at Dunmore, I found the same grey conglomerate which composes the central chain. The coast from this point to the S. E. crosses the strata, which this conglomerate supports diagonally, and the alternations of pink slates and conglomerates, similar to those which I described as occurring at Dingle harbour, may be traced as far as Ventry-head. After passing Dunmore-head to the north, and at the bottom of the first little bay I found some alternations of chloritic slates in the thinner beds, much contorted and associated with quartz, presenting a mixture identical in appearance with that of the *post*, which I before described to you as occurring in the Caernarvonshire slate quarries. As I approached Doonquin, I found a series of purple, yellow, and green soft slates, vieing in colour with the sands of Alumbay; they contain arsenical pyrites, and abundance of nodules of a white compact substance, of which I lay specimens on the table. To the north of the stream which falls into the sea at Doonquin, I found a bed of brown sandstone, containing abundance of fossils, principally of the same bivalve—I found only one trilobite, but it would require much more time than I could then afford, to ascertain whether other varieties of fossils might not be thinly scattered through the mass of the prevailing species. The brown slaty sandstone in which they are most evident, does not occupy a thickness of more than from twelve to twenty feet, but they may be seen as clearly, if not as frequently, in the underlying rock into which this sandstone appears to pass. This rock is extremely hard, and of a deep purple colour, and a little further to the north, it assumes a very remarkable character; the cliffs are very high and broken into vast masses, which appear so little destructible by the action of the elements, that they preserve the sharpest angles and reject vegetation. In some of the masses the quartz pebbles and conglomerate structure of the neighbouring hills is easily to be recognized; in the lower parts of the cliff, to which I had great difficulty in obtaining access, I found all trace of stratification merged in a columnar structure, presenting sometimes all the forms of the pillars of the Giant's Causeway, even to the replacement of the angles.

The rudeness of the structure may be seen in the annexed sketch, (Diagram B,)—the rock is of a fine texture, contains minute chrystals of feldspar and carbonate of lime, and rings under the hammer as sonrously as bell metal. Maran mountains and headland, consist of the coarse grey flags; to the north of it, we meet again with green and yellow slates, and chloritic veins associated with quartz, and then a low sandy plain, the only part of the whole section in which the rocks are not exposed. This extends to Ferriter's cove, where we meet with hard arenaceous rocks of about fifty feet in thickness, in which I did not find any remains; these are succeeded by a thickness of about fifty yards of brown sandy slates, containing abundance of fossil remains in the state of casts; they are as before described at Doonquin, principally of one species, which I believe has obtained from the Swedish geologists the name of Orthis, but of which I can find no description in any of the works in our Libraries. There is also a fossil which I have not elsewhere seen, and which, I suppose to be a coralline, these beds are succeeded by firm flags of a coarse quality, and containing fragments of the pink-coloured slates; these are again succeeded and alternated with, by hard pink slates and sandstones for a distance of about fifty yards, when I met with a mass of rock apparently obtruded; it has joints not conformable with those on either side, but representing a great arch, the upper part of which is soft, green, arenaceous, and containing brown cavities, which is supported by a mass of feldspathic porphyry. In the adjoining rock are found little beds of specular iron, a constant companion of volcanic products of a more recent and undisputed nature. I subjoin a sketch of the junction. (Diagram C.) After this I found about 100 yards of thick coarse flags, a somewhat greater distance, occupied by alternations of slates, conglomerates, and red sandstone, and then a .great mass of conglomerate, of which are composed Sybil-head, the Three Sisters, and Ballydavid, these rocks gradually increase in elevation until their dip is between 80° and 90°; the conglomerate is exactly what I have described as occurring at Brandon-head; it is red and very coarse, the cementing matter bearing a very small proportion to the mass of rolled pebbles of jasper, quartz, and granite; I found this red conglomerate breaking up through the sandy level at the bottom of Smerwick bay, and in the same line of direction with the grey rocks of Maran headland.*

You will perceive in this section a very remarkable repetition of similar rocks, leading us to an almost necessary conclusion that the fossiliferous beds at Prince Ferriter's cove and at Doonquin, were formerly part of the same, or very nearly

* These rocks contain a large proportion of iron, and as the peroxide of that metal in a state of purity possesses a reddish brown colour, but when precipitated from its solution, and exposed to ignition, becomes black. We should, perhaps, be not justified in attaching much importance to the difference of colour in the conglomerate of Brandon and Sybil-head, that the former should be less destructible by the action of the element, would be another effect naturally produced by the action of fire, as the ignited peroxide becomes soluble with much difficulty in acids.

I have seen the conglomerates of what Mr. Trimmer considers to be the *red marl* in Caernarvonshire, altered by the passage of a trap dyke, so as to present within 100 yards all the changes from a soft red conglomerate to a dark grey hard rock scarcely distinguishable from that of Brandon mountain.

the same formation; but how to connect them and assign to them their proper place in the series, is a matter of great difficulty, owing to the beds having all the same dip without any apparent rupture between them. Before I offer any attempt at the solution of this difficulty, I must call in the aid of analogy, and direct your attention to a fine natural section exhibited in the valley through which the high road from Bangor to Ogwen, in Caernarvonshire, passes. I have before described the position which the roofing slate in the Penryhn quarry occupies as lying under the coarser slates and conglomerates, of which the mountains in the interior are, I believe, principally composed. In pursuing these rocks in the ascending order, I found an uninterrupted succession of finer and coarser conglomerates, dipping at an angle of about 40°, and extending as far as the lake called Llyn Idwal, a distance of about three miles; these rocks are in appearance exactly similar to those which I have described as constituting the central mass of the Dingle peninsula. At Llyn Idwal, there is a great synclinal line. The situation of this lake will be easily remembered by those who have been in the habit of travelling that road; at the head of the valley there is a picturesque waterfall and a bridge crossing at the point where two streams unite, one of these streams flows from Ogwen pool, the other from Llyn Idwal, situated at the south of the road, the precipices which overhang the lake (and which have been long known to those botanists, whose zeal lead them to tread their dangerous steeps in search of anthericum serotinum, and and other rare plants) expose a magnificent section, in which we ascend through compact greenish slates to the upper beds consisting of slates, in appearance very like those of Ferriter's cove, and containing fossils apparently similar, and on the eastern side with a columnar structure; the pillars are from three to five inches in diameter, very regularly formed, and placed so as to dip regularly at an angle of from 80° to 85° to the east, thus being as independent of stratification as I have described cleavage to be, and indeed following exactly the same law. In these pillars, I found distinct traces of shells, as I did in those of Doonquin; the fossils here are not very distinct, but in tracing the beds along the line of direction we find them more clearly exhibited in Llanberris and Snowdon; further on to the south-west, and in the neighbourhood of Pwllheli, there is a rock with a regular jointage as if of stratification, and besides distinct traces of spheroidal concretion. It abounds in very perfect casts of shells, and some remains of the shells themselves; they are bivalves, apparently the same as those before described. I only found one univalve, probably a pileopsis, and it fell to pieces when I was trying to detach it. Professor Sedgewick, has informed me that he cannot bring this rock into co-ordination with the others; but it is evidently not very far out of the line, and in Mr. Greenough's map the junctions of the overlying rocks appear to follow the same line of deflexure; the shells here are full and round, on Snowdon they are flatter, and at Llyn Idwal very much compressed indeed. From this analogy, I think I gain ground, for the presumption that the fossiliferous beds at Ferriter and Doonquin, are among the uppermost beds of the formation exhibited in the section; for their actual position I cannot account further than by the supposition that there are three parallel lines of elevation which broke up the undermost strata, and exposed their upturned edges, forming in two instances the great central chain, and its continuation to Dunmore—the elevation of the rocks between Dunmore and Maran—and in a third instance, to the north, of Sybil-head, Ballydavid and Brandon-head, in which latter we find trace of something like an anticlinal or overlap. The variation in the line of strata, as shown upon the map, would favour the idea of the elevation of the central chain in a mass much thicker than that of its western extremity.

The third section I made was from Ballybunian to Dunkerron, (section 3,) the slates or shales of Ballybunian, have been before described to you mineralogically; and of the magnificence of the ocean caves, I really feel that no pen could give an adequate description. I shall merely express my belief that the rocks are the equivalents of the lower beds of the carboniferous limestone; rocks with the same characteristics of a rhomboidal slaty fracture and aluminous efflorescence, are to be met with in many of the quarries in the neighbourhood of Dublin, and in the line of junction between the limestone and the siliceous flags, between Castle-island and Tralee. At Ballybunian they rest upon a limestone in no way distinguishable from the calp, or black quarrystone of Dublin; this is again supported by a considerable thickness of a limestone, identical in appearance with that which forms the brown island in the lower Lake of Killarney, and that upon which the castle opposite Kilworth upon the Blackwater is situated. It is a remarkable rock, and consists of alternations of limestone and chert, of a few inches in thickness; the surfaces of the laminæ of hornstone are not smooth, but as irregular as any of the flint nodules in the English chalk. In proceeding southwards, we meet with siliceous rocks, dipping still to the north, and extremely hard, and when exposed to the action of the sea, or more properly speaking, in the vicinity of the sea, of various colours, red, yellow, &c., and in some veins decomposing into a white slate, not distinguishable from some of the Ballybunian specimens. To the north, I found again the limestone filling the plains of Ardfert and Tralee, and a hill of siliceous flags and sandstones breaking through it between these two places. The limestone of Tralee valley rests to the south, upon the sandstones of Cahirconre, or Bartnagown, of which I must give a somewhat more detailed description. I have before described it as ending to the west abruptly, in a valley which traverses from Inch to Ballygobbin, I went from Ballygobbin for some distance along this valley, and then ascended the largest watercourse that furrows the mountain. The mountain for more than half the ascent is composed of exactly the same conglomerate, that I have before described in Brandon and Connor-hill ; at Ballygobbin it appears to dip to the north, but higher up it is apparently perpendicular ; but, indeed, in this part I did not find it any where very well exposed. Mr. Griffith has informed me of his having found a black slate, like roofing slate, further to the south in the same valley; this, the analogy, which I have pointed out between this conglomerate and the Caernarvonshire rocks, would lead us naturally to expect.

On the south-east and north, this mountain is mantled over by three distinct beds of red sandstone ; a valley runs from the summit eastwards, in which these are beautifully exposed ; it is a very perfect instance of a valley of elevation. The upper bed is of a fine red sandstone, of about 100 feet in thickness ; this is succeeded by about 100 feet of a coarse conglomerate, identical in appearance and constituents with that of the Gaulty mountains ; both of these have rectangular joints dividing them into cubical masses ; beneath this is a red sandstone of apparently great thickness, with a fine cleavage, nearly perpendicular, and joints which tend to divide it into rhomboidal masses. Its dip is at an angle higher than the overlying conglomerate ; but where I found the two rocks actually in junction, I really could not decide whether they were conformable or otherwise ; this, however, is a point upon which I am inclined to be very cautious ; for I feel convinced, that there is no more frequent error committed in geological observation than that of too hastily concluding upon the unconformability of overlying rocks.

These same sandstones appear again to the south to rise from under the limestone of Castlemaine, and form the chain of Magillicuddy's Reeks, of which Caranthuel, across the summit of which I carried my section, is considered the highest land in Ireland. In Caranthuel there is one great anticlinal, besides a great many flexures upon a smaller scale, so that the actual thickness of rock need not be very great, compared with the mass of mountain which it composes. In a peak west of the summit there is an unbroken anticlinal, (Diagram D,) in which the ascending and descending beds actually touch or run parallel to each other; this shows the great pliability of this formation, a pliability which is found in a remarkable degree in these sandstones and the slate rocks which immediately cover them. In proceeding southward from the Reeks, I found the mountains of Coomaduagh, Knockavoilagh, and Tallaght, composed of the same rock; a compact, homogeneous, siliceous sandstone; it is of a greenish or brownish colour; it has one peculiarity, that of flying in pieces on the application of heat, a property which the peasantry avail themselves of in clearing the tillage lands of boulders, by lighting fires upon them; the dip is to the south, constantly from Coomaduagh to Dunkerron; but I suspect that the principal heights which I have mentioned, owe their elevation to three separate up-turnings of the same beds. At Dunkerron this rock is covered by a very light coloured and laminated limestone, apparently destitute of fossils; and I may mention it as a remarkable fact, that the only place where I have observed a rock of exactly the same character, is on the opposite side of Ireland, exactly in the line of the *strike* of this rock, namely in the valley of Middleton, which is filled with a bed of a similar laminated limestone, which lies upon, but does not pass into, if, indeed, it may not be said to lie unconformably upon the compact and fossiliferous limestone, which is in that neighbourhood quarried as a building stone.

ON THE DILUVIAL OR NORTHERN DRIFT OF THE EASTERN AND WESTERN SIDES OF THE CAMBRIAN CHAIN, AND ON ITS CONNEXION WITH A SIMILAR DEPOSIT ON THE EASTERN SIDE OF IRELAND, AT BRAY, HOWTH, AND GLENISMAULE.

BY JOSHUA TRIMMER, F.G.S.

PART I.—THE EASTERN SIDE OF THE CAMBRIAN CHAIN.

WHEN the word diluvium occurs in the following pages, it must not be understood as applied in the sense in which it was originally imposed, namely, to denote the supposed effects of the Noachian Deluge, or even of any partial inundation within the historic æra, but merely as a convenient mode of designating by one word, instead of several, those masses of water moved detritus, which it appears necessary to distinguish from river gravel on the one hand, and from raised beaches, and marine formations of gradual accumulation on the other.

These detrital deposits which constitute the loose covering of large portions of the earth's surface, offer a fertile field of research, which has hitherto been too little explored. The study of them is attended with some difficulties, from which that of the solid strata is exempt. These difficulties Geologists appear unwilling to encounter; and yet they must be grappled with before we can pretend that we have deciphered the entire record of the changes which have taken place upon the surface of our planet, or that we have discovered all the agencies employed in the formation of the stratified rocks.

Sir Walter Raleigh is said to have destroyed the second part of his history of the world, because he could not obtain any satisfactory account of a street quarrel which took place under the window of his prison; and before we decide too confidently that all the ancient Strata were produced by causes now in action, and acting with no greater intensity than at present, it would be well to ascertain whether the first deposit we meet with in the descending order, which intervenes between the ancient state of things and the present, is not one of the residual phenomena of Geology which can only be accounted for by having recourse to causes, which have either ceased to act, or are acting now with diminished force.

The discordant opinions held by Geologists respecting the history of transported matter, to which the term diluvium was once so generally applied, appear to have arisen in a great measure from hasty attempts to arrive at a conclusion from insufficient data.

The field to be explored is so extensive, the phenomena to be observed so numerous and complicated, and demanding such minute observation, and such nice discrimination, that were all the present race of Geologists to devote their energies exclusively to this subject, many years must elapse before we should be in possession of sufficient evidence to enable us to arrive at general conclusions respecting the detrital deposits of any extensive regions of the earth.

Before we discuss the various opinions now held as to the origin of the transported matter of the district to which this memoir relates; it may not be amiss to take a rapid retrospect of the older theories which have successively prevailed respecting detrital deposits in general, and to note the steps by which we have attained our present position.

It was a favourite doctrine of the Huttonian school, that all beds of gravel were the effects of atmospheric erosion on the surface of our present dry land, and when not composed exclusively of the debris of the subjacent rocks, their transport was ascribed to the agency of rivers, and other local forces of small amount, acting during long periods of time; and they were thought to afford indications of the remote epoch at which our present continents had emerged from the ocean. One of the most distinguished followers of Hutton was the first, however, to point out evidence of the passage, over the summits of the hills near Edinburgh, of a large body of water, charged with gravel and boulders, which had scratched and furrowed the surface of the rocks over which they had passed; and he considered that the average direction of these furrows, and the sources whence some of the transported materials were derived, afforded indications of the course of the current. These observations, extended and generalized by Smith, Conybeare, Sedgwick, and Buckland, in the south western, central and northern parts of England, shewed that while a considerable proportion of the fragments contained in the detritus of these districts, was derived from the nearest rocks, it afforded others which were only to be found in places at considerable distances to the North and West; and these deposits were not confined to the vallies, but were distributed over wide plains, on the slopes of hills, and on ranges of high ground, where, as Professor Phillips has said, no "existing streams could carry them—no imagined lakes could leave them," so that some other agency must have been employed in their transport.

Similar researches were extended to Ireland, with similar results. On the continent of Europe a large portion of its Northern regions, from Holland to central Russia, was found to be strewed with blocks and gravel derived from the mountains North of the Baltic, and the North Eastern continent of America, afforded indications of a similar transport of detritus from the North.

The celebrated cave of Kirkdale was next explored, and proved to have been, during a long period, a den of hyænas, whose remains, with those of the animals they had dragged in for food, were enveloped in a single bed of mud and sand, encased in a single crust of stalagmite. Similar mammalian remains occured in the transported gravel of the neighbourhood, and it was thence inferred that this part of Yorkshire, as well as those other districts of England in which ossiferous caverns occurred, had, for a long period been dry land, and that the last tenants of the Kirkdale cavern, had been destroyed by that great inundation which had transported boulders of granite from Shap-fell to Flamborogh-head.

These phenomena combined with those observed on the continents of Europe and America, and with the notices of bone caverns and mammalian remains, in superficial deposits, which poured in from all quarters of the world, gave rise to the diluvial theory of Buckland, which ascribed all such deposits, and the excavation of vallies, to a general deluge within the historic æra. "We saw," to use the words of Professor Sedgwick, " the clearest evidences of diluvial action, and we had in our sacred histories the record of a general deluge. On this double testimony we gave unity to a vast succession of phenomena, not one of which we perfectly comprehended and under the name of diluvium, classed them all together."* The fact that the remains of man and his works had never been found in these diluvial deposits, was totally disregarded: such remains it was said, would probably be discovered when those regions of the earth, which had been the earliest abodes of the human race should be Geologically explored.

But this diluvial theory notwithstanding the ready reception which it experienced, and the high degree of popularity which, for a time it enjoyed, was soon destined to give way before a greater accumulation of facts. As our knowledge of Tertiary Geology extended, it was found, that the upper marine Strata of the Paris basin were not, as had been erroneously supposed, the last regular formation on the face of the earth, succeeded immediately by the diluvial catastrophe, but that there existed, in various parts of Europe, numerous lacustrine and marine strata, affording indubitable evidence of gradual accumulation, which had been confounded with the diluvial deposits; and there was also the clearest evidence that these tertiary strata belonged to at least, two zoological epochs, passing on insensibly into each other, and into the epoch of the Paris basin on the one hand, and that of existing species on the other.

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* Sedgwick's Anniversary Address.—Preceedings Geological Society, vol. I. p. 313.

It appeared, likewise, that the mountain chains of Europe were not all contemporaneous, but that they had been elevated at successive epochs, and that in some cases, the same chain exhibited proofs of more than one upward movement, during which masses of detrital matter had been shot off its flanks. Thus two distinct diluvial accumulations were observable in the region of the Alps, and, on the other hand, in central France, and some other places, no traces whatever of diluvial action could be discovered. Instead, therefore, of ascribing the diluvial phenomena to one general deluge, some geologists began to have recourse to a number of local inundations, occasioned by the agitation into which the water of the ocean was supposed to have been thrown, by the sudden upheavement of portions of its bed: while others insisted that there was no evidence of elevations of mountains, sufficiently sudden to generate waves capable of desolating any large portions of a continent at once. They would allow of no movements exceeding in extent those of a common earthquake, to the repetition of which, at distant intervals of time, or to a process even still more gradual, they attributed the rise of the Alps and the Andes.

A new class of phenomena had now begun to attract attention, namely, those which indicated slight oscillations of the land on the coasts of Naples, Sardinia, near Lisbon, and in Jamaica, as well as in other countries, since they had been inhabited by man. These countries were either the seats of active volcanoes or subject to the shocks of earthquakes. But instances were collected of local displacements of the relative levels of land and sea, in countries not subject to volcanic action. Such changes, the date of which could not be ascertained with more precision, than, that they had taken place since the creation of existing species of molluscs, were noticed by Mr. Hennah, at Plymouth, by Captain Vetch, in the Isle of Juna, by M. de Boblaye, in the Morea, and, not to multiply instances, by Brogniart, and Von Buch, in Scandinavia, since confirmed by Lyell. These are all indisputable cases of raised beaches, exhibiting incontrovertible evidence of the long continued action of water, and, in some instances, of the repetition of movements of elevation. Such evidence consists:

1st. In the succession at different heights above the present beach, of small terraces of smooth round pebbles, among which shells and fragments of shells were deposited.

2dly. In lines of worn rock at various heights, like those produced on rocky shores by the action of the waves along the line of high water.

3dly. In holes drilled in calcareous rocks by boring molluscs

4thly. In Balani, adhering to the rocks, as in the case of Scandinavia; and if these indications leave no doubt of the long continued action of the sea, on the spots where these raised beaches occur, so the various levels at which they are found, even on different points of the same coast, render it equally evident, that the change of level was occasioned by local elevations of the land, not by a general depression of the ocean, as supposed by Brogniart. The interest excited by these new and striking facts, had now diverted the current of Geological speculation into an opposite direction, from that in which it had lately flowed, and from the one extreme, of having generalized too hastily on diluvial phenomena, Geologists began to run into the other; of endeavouring to exclude diluvial action, from the list of geological agencies—to expunge the very name from geological nomenclature—to forget all the evidence which had been collected, of the passage of large bodies of water over the land, and, in every mass of transported gravel, in which marine shells of existing species were discovered, to see a raised beach, or a marine formation of gradual accumulation, regardless of the proofs which, in many cases, existed of such deposits being due to the sudden and transient action of the sea.

It will, therefore, be the object of the present paper to shew, that the stream of Northern drift, which extends from the foot of the mountains of the lake district of England, through Lancashire, Cheshire, Shropshire, and still lower down the valley of the Severn, on the coast of the Cambrian chain, and also down the Western side of the same chain, from Chester to the South-western extremity of Caernarvonshire, is of this latter description; and that the title of a raised beach, or a sea bottom, is improperly applied to it. And I shall endeavour to shew the identity of the Northern drift of England and Wales, with that of the Western side of Ireland.

I was among the first to bring under the notice of Geologists the occurrence of fragments of marine shells, of existing species in diluvial gravel, in which the bones of extinct species of mammalia had previously been found. In the year 1831, I communicated to the Geological Society of London, a paper on the diluvial deposits of Caernarvonshire, between the Menai Straits and Snowdon, and on the occurrence of marine shells, in sand and gravel, near the summit of Moel Tryfan; which I then estimated at 1000 feet, but which appears by the Ordnance Survey, to be 1392 feet above the level of the sea, and distant from it six or seven miles, both on the side of Menai straits, and of Caernarvon bay. This paper was communicated a few months after Professor Sedgwick, had abjured from the chair of the Geological Society, the diluvial hypothesis of Buckland, as a philosophic heresy, of which he had himself been a zealous propagator, and shortly after the appearance of the first volume of the principles of geology, in which Mr. Lyell had revived the Huttonian doctrine, that the physical operations now in progress on the earth, were sufficient, granting adequate time, to explain all the phenomena of Geology. In that paper I shewed, that all the flanks of the Snowdonian chain, and the lower ground between the mountains and the Menai, were covered by great accumulations of gravel, sand, and boulders, derived for the most part from the rocks of Snowdonia, but containing occasionally fragments of various kinds of granite, generally rounded, but sometimes angular, which must have come from Cumberland, Scotland, the Isle of Man, or Ireland. These were accompanied by chalk flints, which could have been derived from no nearer source than the county of Antrim; and also by fragments of Carboniferous limestone, and marine shells, apparently identical in species with those now inhabiting the adjacent seas. I pointed out two other localities, in which similar marine remains accompanied by erratic fragments, had been discovered; one on the low cliff near the entrance to Beaumaris, the other on Moel Faban, on the opposite side of the valley to the Penhyn Quarry, and at about the same elevation as on Moel Tryfan.

I pointed out, likewise, two conditions under which the rock occurred, beneath the diluvial deposits, as exhibited in the numerous excavations made within the district, in opening slate quarries and forming railways. The one presents traces of an ancient weathering to a considerable depth, so that the rock will not yield slates for 30 feet from the surface. These weathered tops are frequently bent down, scattered, and broken beneath the incumbent head of diluvium. Sometimes a mass of them has been lifted up bodily from the rock, and enveloped in loam or clay, with boulders of more distant rocks, above and below the mass of weathered tops. (Section I.) In the other condition of the rock there are none of these indications of an ancient weathering, and the diluvium rests on a flat surface ot rock, then said by the workmen to be "solid" because it yields slates at the surface, particularly when the superincumbent mass is sufficiently deep and argillaceous to have excluded the action of the atmosphere. These flat surfaces of rock, which appear to be some of its horizontal joints laid bare, are generally scratched and furrowed, as described by Sir James Hall on the Costorphine hill, as if from the passage of heavy blocks over them; they are also covered with numerous indentations, like those from the strokes of a pick, occasioned apparently, by the rolling over them of angular masses of hard rock. In Wales the furrows have no uniform direction, but it varies with the local configuration of the country. Some of the large blocks have a rounded and polished surface, which is occasionally scored with a few deep scratches: and I accounted for this by supposing that after they had been polished and rounded in the bed of a river, they had received the scratches, during a violent transportation to their present situations, in company with angular blocks, and passing over sharp peaks of rock. The shells collected from Moel Tryfan at different times have amounted to ten whole specimens, besides many hundred of fragments, among which Mr. Lonsdale could not detect any extinct species. At the time that paper was read, only two whole specimens had been found. The genera, only, are therefore enumerated in the abstract published, in the proceedings of the Geological Society, and there was at that time a great disposition to regard the deposit as of the era of the crag.

Mr. Gibberston had previously observed shells of existing species in gravel and sand near Preston, and Mr. Underwood had noticed furrows and dressings, on the surface of rocks laid bare in forming the parliamentary road, in the central regions of Snowdonia.

In the second volume of Mr. Lyell's work, he adduced the case of Moel Tryfan, as a raised beach, or a tertiary deposit, of slow accumulation, without assigning any reasons for disregarding the indications which had been brought forward of sudden and transient action.

Mr. Murchison, who was at that time president of the Geological Society, in commenting on my paper in his anniversary address, observed. "This striking phenomena of the sea having overspread the western part of our island, at a period so comparatively recent, led me, in a recent journey along the north-west coast of England, to endeavour to ascertain whether the lower country of Lancashire, had partaken of similar operations, and I was induced to suppose this might have been the case, from the occurrence as stated by Mr. Gilberston, of marine shells of existing species, at Preston, in Lancashire.

I was fortunately able to confirm this discovery, and to observe similar phenomena over a considerable extent of country, occupying the ancient estuary of the Ribble; sands, marls, and gravels, occasionally constituting terraces, are spread over this great area; sometimes in finely laminated beds, but for the most part loosely aggregated, and bearing a great resemblance to the arrangement of the same materials, now in the act of formation on the adjoining shore. Many of the shells found in these beds far inland, and at heights extending to 300 feet above the sea, are perfectly identical with existing species. These circumstances have induced me to dissent from the theory, which would refer all these deposits to a diluvial current, and I have inferred, that the ancient shore of Lancashire, and the estuary of the Ribble, in which the above materials had accumulated during a long protracted epoch, were elevated and laid dry after the creation of many of the existing species of molluscs." *

Professor Phillips in a recent publication,† after citing Mr. Murchison's account of the Preston deposit, as a raised beach, adds: "In the above district occur beds of sand, marl, and gravel *under the ordinary diluvium, with erratic blocks* locally full of shells." From the construction of the above sentence, it is not very clear whether locally full of shells refers to the beds of sand clay, and marl, or to the diluvium. I have had no opportunity of examining the deposits near Preston, but in the southern parts of Lancashire, I have seen fragments of shells in the ordinary diluvium, with erratic blocks. Specimens of shells collected by Mr. Murchison, at Preston and deposited in the museum of the Geological Society, appear to approach much nearer to the condition of whole shells, than those met with in south Lancashire, Cheshire, Shropshire and Wales.

In the beginning of 1833, I made another communication on the subject of a cliff, about 20 feet high, on the left bank of the Mersey, at the entrance of the Bridgewater canal, near Runcorn. In that cliff fragments of marine shells, apparently of existing species, occurred above the level of high water in reddish sand, and clay about 14 feet thick, such as would have resulted from the destruction of the arenaceous and argillaceous beds of the Poikilitic formation of the neighbourhood. In this sand and clay were imbedded a great variety of pebbles, and a few blocks estimated to weigh half a ton each of rocks foreign to the district, namely, granite, syenite, greenstone, limestone, greywacke, quartz rock, and sandstone, accompanied by marine shells of the same species as those obtained from the summit of Moel Tryfan. This shelly sand and clay, containing erratic blocks, I described as covered by a layer of black vegetable matter, from half an inch to three inches thick, over which was yellow silty sand from three to six feet thick, with a few pebbles but no shells. Dr. Buckland, who has since examined the spot, informs me that he should describe the black line as sand coloured by carbonaceous matter rather than as peat; and he explains its formation thus: a species of grass which grows on the sand, after penetrating to a certain depth, sends out running roots, which becoming carbonized, have stained the sand for a thickness of several inches. Specimens of these carbonised roots he exhibited at the Geological Society under the name of the Radical coal formation. Granite pebbles and boulders were much more numerous, and larger here than on the summit of Moel Tryfan. I also found small erratic gravel composed of the same materials, covering the sandstone quarries, near Weston, in the same neighbourhood, more than 100 feet above the sea, but could not detect in it any fragments of shells.*

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* Proceedings Geological Society. vol. I. p. 366.

† Lardiner's Cyclopœdia, Geology, vol. I. p. 302

In May 1835, Sir Philip Egerton communicated to the Geological Society, an account of a bed of gravel containing marine shells of existing species recently exposed at Willington, near Tarporly, in Cheshire. The bed was composed principally of fine grained gravel and pebbles from one to six inches in diameter, which had undergone considerable attrition, but presented a flattened, not a spheroidal form. They consisted chiefly of granite, slate, chert, porphyry, greenstone, amygdaloid, new red sandstone, coal measure sandstone, and quartz pebbles, from the conglomerate of the new red sandstone districts. The shells were all of existing species thickly disseminated through the whole deposit. They were chiefly fragments, but contained some whole specimens, and were in a very friable state. The thickness of the bed could not be ascertained, but in sinking a well at Willington, a similar bed of gravel (whether containing shells or not was not known) had been penetrated to the depth of 12 feet, before the new red sandstone was reached. This bed of gravel was about 70 feet above the level of the Mersey, distant 9 miles, and was separated by a well defined line from about 20 feet of the ordinary diluvium of Cheshire, consisting principally of sand, containing pebbles and boulders of granite, slate, greenstone, and other rocks; and Sir Phillip Egerton inferred that a bed of gravel had been deposited on the shore of the ancient sea, since the existence of some of the species of shells now inhabiting our seas, that an elevation in the relative levels of the land and sea to the extent of 70 feet, had taken place since its deposition, and that it had been covered by an accumulation of diluvium, twenty feet in thickness.*

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* Proceedings of Geological Society, vol. 1 p. 419.

Fragments of shells had been found in the diluvial cliffs of Holderness by Professor Phillips; and Mr. Mantell, in his chapter on diluvial deposits, in the Geology of the south-east of England, had it described, under the name of the Elephant bed. On the coast between Brighton and Rottingdean, a mass 50 to 60 feet thick, formed of the ruins of the chalk strata, and resting upon a raised beach, consisting of fine sand, from one to four feet thick, covered by shingle, from five to eight feet thick, composed of pebbles of chalk flints, granite, and porphyry, and occasionally enveloping masses of broken shells. The elephant bed contains bones and teeth of the ox, deer, horse, and Asiatic elephant, sparingly dispersed through it; generally more or less water worn, but in some instances they are quite entire and cannot have been subjected to the action of the waves.†

Mr. Smith of Jordan Hill, near Glasgow, had described in No. 4, of Thomson's Records of Science, and subsequently at page 427 of the proceedings of the Geological Society, vol. II. two superficial deposits in the west of Scotland, the lowest in some districts called "Till," consists of unstratified clay confusedly mixed with boulders, occasionally containing bones of stags, and tusks, and bones of elephants, sometimes associated with marine shells The upper deposit is composed of finely laminated clay, sand, and gravel, containing at 40 feet above the sea, and 8 miles from it, bones of fishes and sea fowls, fragments of sea weeds, crab's claws, and numerous layers of shells of existing species; but human remains and works of art have never been discovered in it. The greatest observed thickness of the lower deposit is 70 feet, and the upper or tranquil deposit is found at heights varying from 30 to 70 feet.

A short time before the Dublin meeting of the British association, Dr. Scouler had announced the discovery of fragments of marine shells of existing species in gravel, sand, and clay, at Howth, Bray, and Glenismaule. ‡ At that meeting of the association, Mr. Griffith produced in the Geological section specimens of shells from the valley of the Slaney, near Wexford; the occurrence of which in that locality had been pointed out to me by Captain Charles Le Hunte, and from information which I received from him, I have reason to believe that this deposit is covered by a tumultuous accumulation similar to that of Howth and Bray, which I have traced as far to the Southward as Arklow.

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† Mantell's Geology of the South-east of England. p. 34.

‡ Memorandum of objects of Geological Interest in the neighbourhood of Dublin. Dublin, 1836.

* Proceedings of Geological Society. vol. II. p. 189.

Between these discoveries of shells at Tarporley by Sir Philip Egerton, and on the east coast of Ireland by Dr. Scouler, I had met with another case of fragments of marine shells, in a very unexpected situation. In travelling to London, I had noticed from the mail, at Norton, five miles east of Shrewsbury, a considerable body of peat, containing prostrate trunks of trees, and covered by a mass of sand, loam, and gravel, which had been cut into in widening the road. Expecting to find here the peat formation of Runcorn more largely developed, I halted for a few hours on my return to Wales, in order to look at it, when I saw to my great surprise, that in this situation, so far inland, the gravel and sand covering the peat and trees, contained marine shells, and erratic blocks of the same kind as I had observed at Runcorn, though in less abundance. My time would only permit me to give the deposit a very slight examination, but as I considered that the appearances indicated the growth of a forest, its conversion into a peat bog, and subsequent submergence beneath an oceanic current, and that if this view of the case were established it would be decisive of the question, whether this shelly gravel had accumulated gradually at the bottom of the sea, or had been spread by a sudden irruption over pre-existing land, I sent immediate notice of it to the Geological Society of London, stating, at the same time, the opinions of the workmen who had been employed in making the excavation, that the trees had been laid across the bog, as the foundation of an ancient road. I likewise pointed out very precisely the situation of a fir tree, in a vertical position, which I traced from the shelly gravel into the peat, leaving it there because I was unwilling to disturb it, before it should have been seen by some of the leading members of the Geological Society, whom I urged to visit the spot, either to confirm my description, or to point out its errors. On his return from the Dublin meeting of the association, Mr. Murchison, accompanied by Dr. Dugard of Shrewsbury, dug out the supposed fir tree, which proved to be a pile sharpened at the end. He thus established the account given by the workmen, and destroyed my submerged forest, but confirmed my discovery of marine shells of existing species, in the superficial gravel of central England.

Mr. Murchison, subsequently observed these shells in other localities, over a wide area in Shropshire, tracing them at intervals from Marington Green, north-west of Shrewsbury, by the Wrekin and Wellington to the high grounds between Bridgnorth and Wolverhampton, at least 60 miles inland, and at heights varying from 300 to 600 feet, collecting a considerable number of species, which having been examined by good conchologists, including Dr. Beck of Copenhagen, proved to be identical with species now inhabiting adjacent seas. Section II. represents the arrangement of materials in one of the mounds of diluvial drift at Norton.

It may appear rather singular, that these shells should have escaped the notice of so accurate and indefatigable an observer as Mr. Murchison, who, about a year before, had communicated to the Geological Society a memoir on the gravel and alluvial deposits of those parts of the counties of Hereford, Salop, and Worcester, which consist of old red sandstone.* In that paper, it was stated, that all the detritus within the above region, (extending from the environs of Ludlow, to the south-west of Kington, and east by the Abberley Hills) was derived from adjacent rocks, and that no fragments from distant rocks had been borne into it, while he had noticed on the *northern* confines of the old red sandstone, and in great abundance on the flanks of the Wrekin, a great variety of granite to which he ascribed a northern origin, making no mention of these boulders being accompanied by shells. It must be observed, however, that throughout the whole region of the northern drift, the shells are only locally distributed, and that in most cases, where they have been discovered we are indebted for a knowledge of their existence to artificial sections, scarcely one in an hundred affords indications of marine remains, and I may add, that in Dinas Dinlle, a diluvial cliff on the coast of Caernarvonshire, which I shall hereafter describe, I had searched many times for fragments of shells before I found any, and that even in this cliff, their distribution is so local, and the fragments so small, that on visiting the same spot after the lapse of a year, though certain they were there, I had the greatest difficulty in re-discovering them.

Mr. Murchison had suggested, in the above paper, that the superficial accumulations of the old red sand stone district of Shropshire, Herefordshire, and Worcestershire, might be referred to causes in operation during three epochs, which might hereafter be divided into other distinct periods.

1st. To the currents caused by the elevation of the adjacent

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* Proceedings of the Geological Society, vol. 2. p. 77.

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transition rocks of Wales, when the associated volcanic action was in full activity.

2nd. To the subsequent degradation of the old red sandstone, both when submarine, and during its elevation.

3rd. To various alluvial causes of date, posterior to the desiccation of the old red sandstone, including the erosion of rivers, the deposits of partial lakes, and the accumulation of travertin.

After the discovery of the shells near Shrewsbury, another communication was made by Mr. Murchison to the Geological Society, on the gravel and alluvia of South Wales and Siluria, as distinguished from a northern drift covering Lancashire, Cheshire, North Salop, and parts of Worcestershire. He founds the distinction between these two deposits, on the local nature of the gravel of South Wales and Siluria, on the relation that exists between the distribution of this gravel and the strike and dip of the strata, on the absence from this South Welch and Silurian region of the northern drift with granite boulders and marine shells, and on the superposition, near Shrewsbury, of loam and boulders of northern drift, on certain mounds of Silurian drift.

The northern drift is stated by Mr. Murchison, to range up to the edges of the above mentioned region, its materials consisting of granitic, porphyritic, and other hard rocks, which have been derived from the mountains of Cumberland, and a few perhaps from Scotland. The drift further contains much sand and clay, with many pebbles of a small size, which vary exceedingly in different districts. Thus, in north Salop, near the great outlier of Lias, fragments of that formation are added to the mass. As it advances to the South, the materials become more diversified, the fragments, however, of northern granite and porphyry always existing to identify the drift. Its distinguishing feature is the re-occurrence, at intervals, of large blocks or boulders of northern origin, a great proportion of which lie at various heights on the slopes of the mountains skirting the North Welch coal field, and encumbering the *northern* flanks of the Wrekin and Haughmond hills, while a few have been propelled to the edge of the Silurian rocks, South of Shrewsbury. They prevail, in vast quantities, on the high inland district between Bridgnorth and Wolverhampton, from which latitude they begin to diminish in size, but coarse gravel, composed of the same materials, is prolonged southward, like the tail of a delta, through Worcestershire, until it dies away in the fine gravel and silt of the vale of Gloucester. It was a prevalent belief, that large boulders were usually lodged on the surface of the gravel and sand, but cuts which have been made through mounds of these materials at Norton near Shrewsbury, have proved that the larger blocks occur at considerable depths below the surface, mixed up with shells, and gravel, and clay. This was the locality where I had described the northern drift as covering a peat bog containing trees, and after correcting the error into which I had fallen, Mr. Murchison proceeds to infer, from the evidence of the recent shells, that the tracts covered by them must have remained under the sea during the modern period, and from the continuation of the granitic drift, from the high grounds near Bridgnorth, into the vale of Worcester, he conceives that the sea must, at the same time, have covered the valley of the Severn to the Bristol channel, thus separating Wales and Siluria, on the one side from England on the other. Having shewn, as he conceives, that the Welch and Silurian mountains were partly raised at an earlier period, he points out the Abberley and Malvern hills, as constituting the Western side of a strait of the sea, the eastern shore of which was bounded by the Cotswold hills. He deduces the principal proof of the pre-existence of this eastern coast, from the observations of Mr. H. Strickland, which shew the transport from the East and North-east of fluviatile and land shells, mixed with the remains of extinct quadrupeds, in banks of coarse gravel, following the drainage of the Avon, near where that river empties itself into the Severn, and he asserts that the terrace-like deposits of Cropthorne are exactly those which would have accumulated at the mouth of a river, if the materials had been carried onwards beneath the waters of the adjoining straits of the sea, illustrating his views by analogies from other rivers and estuaries.

With respect to the mode in which these blocks could have been transported 100 miles, he does not think that we have yet been furnished with any full explanation, for, supposing them to have been derived from the shores of Cumberland, and that they extended in a delta from thence, it would appear, that assuming the slightest degree of inclination, viz. 3° which would give adequate momentum to the ordinary power of running water upon these loose materials, the southern part of the delta, at the distance of only 50 miles from Cumberland, as suggested by Mr. Lansdale, must have been at the vast depth of 13000 feet beneath the sea, in which case, all Wales would have been equally submerged, though we have proof that the mountains of that country had risen to a certain height, previous to the accumulation of the nortern drift. It is further submitted, that under the assumed physical features of the region when the drift was formed, namely, when a great strait of the sea separated England from Wales, submarine currents would not have been powerful enough to propel these blocks, though the question is one that he considers ought to be more completely disposed of by those versed in the laws of dynamics. He then takes into consideration the theory of the transport on ice, shewing that Mr. Lyell has thrown great light on this subject by his observations on Sweden and the Alps, by which it really appears that under certain limitations, " ice floes" may have been " *veræ causæ* in the transport of large blocks, depositing them under seas and lakes, at great distances from the source of their origin. In the Salopian case, however, though it is possible such means may have been employed, there are many arguments which weaken the application of the hypothesis, such as the rounded and worn exterior of the boulders and their diminution in size and quantity, from North to South. It might also be contended, that we have no right to infer a colder climate in our latitude in those days, but this objection he does not consider unanswerable, since it might be replied, that if at the period of the northern drift, England, Ireland, and the Continent of Europe were united by lofty mountains, there might have been a temperature sufficiently severe to have formed annually large bodies of ice on the shores of Cumberland.

Passing, however, over the difficult question of the method of transport, Mr. Murchison states that the greatest of the anomalies hitherto presented by these boulders, is obviated, when we dispel from our minds the idea of their having been carried over pre-existing lands. Having once ascertained that large distributions of them took place *under the sea*, the different heights at which we now find them may, he supposes, be satisfactorily accounted for *by movements of elevation and depression, acting upon the bed of the sea with unequal intensity, raising up shells and boulders which were accumulated at the same period to the respective heights which they now occupy.**

The above is Mr. Murchison's account of the phenomena of the northern drift, and of the hypothesis on which he explains the mode of its distribution, taken nearly verbatim from the abstract of his paper contained in the proceedings of the Geological Society. If there is any difference between his views on this subject and those of Mr. Lyell, it is that the latter would ascribe the elevation of the bed of these Straits of Malvern to a more gradual process, similar to that which appears to be now in action on the shores of the Baltic, or to the successive shocks of a number of ordinary earthquakes, repeated at distant intervals, effecting an elevation of a few feet at a time. In his address to the Geological Society in 1836, he ridicules those geologists who are of opinion that large blocks may have been pushed far over the bed of the sea, and over the land by a succession of waves raised by earthquakes and hurricanes. "Without denying," he says, "that such agency may explain some facts in geology, I may remark that we cannot be too much on our guard against assuming violent catastrophes, where the effects may have been brought about tranquilly, and even with extreme slowness. Let us imagine, for example, a sunken reef of granite in Baffin's Bay, in about 75° north latitude, divided into fragmentary masses, and these masses becoming, year after year, involved in packed ice. In a few months they might be drifted more than 1800 miles to the southward, through the Straits of Belleisle, to the 48° north latitude, the ice moving at a slow rate, no more than a mile an hour. We might even land upon them, and be unable to determine whether they were in motion or not.

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* Proceedings of the Geological Society, vol. 2. p. 336.

After the repetition of these operations for thousands of years, the uneven bed of the ocean, far to the south, may be strewed over with drift fragments which have either stranded on shoals, or have dropped down from the melting bergs. Suppose the floor of the ocean where they alight to rise gradually, like the bottom of the Baltic in our own times. The changes may be so insensible, that pilots may suspect, and yet scarcely dare to insist upon the fact, till its reality is confirmed by the experience of centuries. At length the submarine ridge, covered with the travelled fragments, emerges and first constitutes an island, which becomes connected with the main land, in time, perhaps, the site of a university like Upsala. Here the question is agitated, whether the land is stationary or continually rising beneath their feet. Perchance, they decide that it is motionless, and yet it continues to move upwards "é pur si muove," till by a growth as imperceptible as that of a forest tree, what was once a submarine reef, becomes the summit of an inland mountain.

Here the geologist admires the position, number, and magnitude of the transported fragments, identifies them with their parent mountains, a thousand miles distant to the north, and, in speculating on the causes of the phenomena, imagines mighty deluges, and tremendous waves, raised by the shock of a comet, or the sudden starting up of a chain like the Andes out of the sea, by which huge rocks are scattered over hill and dale as readily as shingle is cast up by the breakers on the beach.'*

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* Proceedings of the Geological Society, vol. 2. p. 384.

Professor Phillips does not appear willing to confine the agency employed in the transport of blocks within the above limits, nor to abandon the word diluvium altogether. In his recently published treatise in Lardner's Cyclopedia, he observes that, "in the British Islands, very considerable tracts of country have been traversed since the land assumed its present general aspect of hill and dale, by currents of water due to some unknown cause which transported rock masses with so great a degree of force, to points so elevated in such directions, and to such distances that we cannot avoid feeling extreme astonishment, and look around in disappointment on the physical processes now at work on the earth for any thing similar; but it is only in particular tracts that the magnitude of the transported rocks is such as to deserve the title of erratic blocks, and among several examples, we know of none which more strikingly exemplify the phenomena, than the dispersion of granite slate and porphyry from the vicinity of the English lakes, because the nature of the rocks, and the limited extent of the region render the observations and inferences more precise, than when reference is made to the Grampians, Lammermuirs, or mountains of Wales."*

He then traces the Cambrian erratics from Shap Fell, shewing how the present configuration of the country had great influence in their distribution. They are found northwards down the vale of Eden to Carlisle, eastward to the foot of the Penine chain, southward, by the Lune and the Kent, to the narrow tract between Bolland Forest and the Bay of Morcambe. From the vicinity of Lancaster, they are found at intervals through the comparatively low country, between the sea and the Yorkshire and Derbyshire Hills, to the valley of the Trent, the plains of Cheshire and Staffordshire, and the "*vale of Severn where they occur of great magnitude.*" He then shews how the great Penine chain, ranging north and south, acted as a natural dam, limiting the eastward distribution of the blocks, which, however, at Stainmoor, a comparatively low part of the chain, 1400 feet above the sea, have surmounted the barrier, so that granite from Shap Fell, which is about 1500 feet, Syenitic rocks from Carrick Fell 2200, and Red Conglomerate from Kirby Stephen, only 500 feet above the sea, have been drifted over the ridge from Stainmoor, as a new centre, they have gone down the vale of York, and by the base of the chalk wolds to the Humber, surmounting the escarpments of oolite and chalk, however, in places; so that blocks of Shap Fell granite lie on the Moors, near Scarborough, and on the wolds near Flamborough Head. He then traces the large quantity of detritus which has been drifted to the south, on the western side of the high mountain border of Yorkshire, and Derbyshire, across the drainage of the Lune at Lancaster, Wyre at Garstary, Ribble at Preston, Mersey at Manchester, Weaver at Northwich, into and beyond the drainage of the Trent and Dee, and *the Severn at Bridgnorth*, shewing, that in no instance have they surmounted the eastern barrier, but lie up against it in the most inextricable confusion, " not to be explained by any thing like the action of the sea on its coast during the most violent storms."

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* Phillips, in Lardner's Cyclopedia; Geology, vol. 1. p. 267.

He had divided his chapter on post tertiary formations, into four sections, erratic blocks, diluvial gravel, ossiferous caverns, and raised beaches. From the consideration of erratic blocks, he passes to that of diluvial gravel, limiting the term to deposits, which, by the abundance of pebbles from very distant parts, require the supposition of extraordinary circumstances for their accumulation, and which possess the character of extreme confusion and almost total want of laminar or stratified structure, pebbles and fragments of rocks of all ages, of different natures, and from different regions lying mixed indiscriminately in clay, many yards in thickness, " which seems clearly to prove that the whole was rapidly accumulated, and that the particles had not time to be arranged according to magnitude and specific gravity; but were heaped confusedly together, by a force of extraordinary energy, and of short duration. Nevertheless, after this distinctive character has been laid down, the case of shelly gravel near Shrewsbury, (which had previously been included among the erratic blocks) and the other cases described by me at Moel Tryfan, and Runcorn, are classed as raised beaches with such phenomena as those presented by the temple of Serapis at Puzzuoli, and the gradually raised and rising land of Scandinavia. In other words, phenomena which astonish us, by the violent and sudden forces which appear to have produced them, and which disappoint us by their dissimilarity to any of the physical operations now at work on the earth, are grouped with others which appear to have been produced by causes now in action, and which astonish us equally by the very gradual process by which they have been effected. Surely there must be some criterion by which phenomena of such opposite characters may be discriminated. Let us now examine the hypothesis of Mr. Murchison, and see how far it is in accordance with the phenomena to be explained. The boulders and shells are supposed to have accumulated beneath the sea, in a Strait which separated Wales and Siluria from England, in the same manner that Anglesey is now divided from Caernarvonshire by the Straits of Menai. The ordinary action of oceanic currents is abandoned, as inadequate to have propelled the blocks the distance required, without giving to the bed of the sea an inclination from the mountains of Cumberland, which would have plunged the whole region of Wales to a depth incompatible with phenomena supposed to indicate the previous elevation of its mountains to a certain height above the surface, and, although some of the objections to their transport on ice are adverted to, yet on the whole, there is a manifest leaning to that hypothesis. But, by whatever means transported, these blocks are supposed to have accumulated gradually, while that part of England remained beneath the sea, and to have been raised to their present irregular heights, by movements of elevation of unequal intensity. Let us suppose the Straits of Menai to be now elevated and laid bare, what would be the phenomena which would be presented to our view? In order to reply to this question, we must examine its shores, and those parts of its bed which are accessible to our observation. On either side, between the lines of high water of neap and spring tides, heaps of shingle, more or less steep, are thrown up. These heaps of shingle are composed of smooth round pebbles, mixed with which are many broken and a few whole shells.

Within these limits, projecting points of rock and large boulders are polished and worn into hollows, by the action of the breakers, and the attrition of the sand and gravel thus kept in motion. Between the high water mark of neap tides, and low water mark, is a gently sloping surface, thickly strewed with pebbles and blocks, with intervening patches of sand. The pebbles on this part of the beach, not being so much disturbed as near high water mark, many of them are found less water worn, calcareous rocks and pebbles are perforated by lithodomous molluscs, non-calcareous pebbles incrusted with Serpulæ and Balani; the lower part of rocks and large boulders are partially water worn, but the upper surface, and any of the lower parts which may be protected from the grinding action of the waves, and moving sand and gravel, are thickly incrusted with Balani. This is observable, to a certain extent, on every shore I have examined, and in many places adhering molluscs are so numerous as to conceal the entire surface. These incrustations become more abundant, as we advance from the position of the shore left dry during the recess of the tide into the region of shallow water, where the blocks and rocks are never wholly uncovered. The small patches of sand between the blocks and pebbles are inhabited by several species of molluscs, and in crevices of the rocks, or between the boulders and pebbles are wedged whole, or nearly whole, shells of *Patella Vulgaris*, *Turbo Littorea*,—*Purpura Lapillus*, *Buccinum Undatum*, *Pecten Varius*, *Ostrea Edulis*, *Cardium Edule*, and *Tuberculatum*, the shells of the bivalves being generally separated, but not always. What the appearances would be at the bottom of the deep channel which is now never exposed to view, I will not attempt to determine—but in the wide part of the straits, opposite Caernarvon, almost the half of the entire breath is occupied by nearly level beds of sand, dry at half-tide, and having a rippled surface, in which Cardium Edule and Solen Vagina are buried, in great quantities, with the two valves united.

Similar beds of sand, though of larger extent, and containing a greater variety of molluscous inhabitants, occur on the Llavan Sands, where the straits expand into Beaumaris Bay.

The narrowest part of the Menai is at the Swilly Rocks, where the tide flows with great violence; but, even in the vicinity of this spot, many smaller bays may be found, sheltered from the current, where mud accumulates, and is inhabited by *Lutraria* and *Turritella Terebra*. Beds of *Mytilus Edulis* are found adhering to the rocks withing the straits properly so called, but in much greater quantities on the muscle banks which supply the pearl fishery of the Conwy.

Between the Orme's Head and Caernarvon Bar three rivers enter the Straits, bearing down mammalian remains with land and fresh-water shells, and thus furnishing analogies to the ancient Avon flowing into the Straits of Malvern. Our rivers are the Conwy, the Ogwen, and the Seiont. They all float down mammalian remains of the genera *Canis*, *Felis*, *Sus*, *Ovis*, *Equus*, *and Bos Taurus;* or, in plain English, dead dogs and cats, a few carcases of sheep and swine, and, occasionally, the remains of an unfortunate horse or cow, besides horns, the refuse of the tanners' yards. The Seiont and the Ogwen are rapid mountain streams, containing, I believe, no fresh-water molluscs; but in floods shells of several species of *Helix* from the land, and of *Lymnea* and *Succinea* from pools and ditches, are floated down. To these we may add, in the Conwy, the large valves of *Unio Margaritifera*, which inhabiting the upper part of the river, are drifted down in floods, and are occasionally found among the marine deposits at its mouth. These bones and land shells are dispersed among the marine remains, where the rivers enter the Straits ; but I know of no instance in which the terrestrial remains of mammalia and molluscs are found sorted by themselves, and covered by gravel and sand, containing exclusively marine remains.

All the species of marine testacea above mentioned, besides others not enumerated, were inhabitants of Mr. Murchison's ancient Straits of Malvern, and are now found in the Menai and on the coasts of Caernarvonshire; but the mode in which the shells are distributed in the ancient and modern Straits is widely different. In the former, fragments of shells are only occasionally met with, and they diminish in abundance the further they recede from the present coast of Lancashire. They occur, for the most part, in a broken state, and, so far, they agree with the high-water beach of the Menai; but that is the only feature common to the two deposits. There are no layers of shells following Laminæ of stratification, and indicating the gradual accumulation of the exuviæ of successive generations. In those mounds of gravel, &c., in which shells occur, they are dispersed indiscriminately through the mass—with this limitation, that they are generally very rare in the sand, and are then found in small veins of gravel traversing the sand. In no section that I have seen, throughout this district of northern drift, whether in Lancashire, Cheshire, Shropshire, or Wales, is there the slightest indication of the marine remains having been deposited on the spots where they have lived and died. There are not even those large accumulations of drifted shells, sometimes constituting entire beds of several feet in thickness, which we see in the crag formation of the eastern coast of England, generally considered a littoral deposit; and however violent we may suppose the currents to have been that flowed through these Straits of Menai, it appears marvellous, if they were ordinary marine currents, that over so wide an area, comprising hundreds of square miles, there should be no tranquil bay, or sheltered nook, in which testacea should be found with the valves united, and quietly enveloped in the sediment which they inhabited. In the Menai, the wider the Straits the more extensive are these beds of tranquil sediment, and the greater the variety of the testaceous inhabitants; and as the Straits which are said to have divided "England Proper" from Wales were so much wider than those which separate Anglesey from Caernarvonshire, they ought to furnish a greater extent of regular strata, exhibiting those evidences of gradual accumulation, of which so many instances have been recorded among the tertiary. In the bed of the Straits of Malvern we have no rocks and boulders polished and hollowed into basins by the action of the waves near the coast; we have no Balani and Serpulæ adhering to boulders and pebbles; we have no drilled calcareous pebbles, boulders, or rocks. This latter circumstance, however, will not be insisted on now—because in those parts of the Salopian drift which I have examined, calcareous pebbles were by no means abundant. I have, however, seen boulders of limestone at Runcorn, and there they were not perforated. This subject will therefore be resumed when we treat of those parts of Wales and Ireland where fragments of calcareous rocks abound in the drifted gravel, containing marine remains.

With respect to the transport of the blocks on ice, it is preferred by Mr. Murchison to a more violent mode of conveyance—because Mr. Lyell's researches in the Baltic and the Alps have given to it the character of a *vera causa;* and certainly when applied to the cases of erratic blocks in the North of Europe and in Switzerland, it possesses some claim to the title, because, on the shores of the Baltic, boulders are frequently enveloped in ice, and so floated away—and because, in the Alps, glaciers charged with such blocks descend with them into the vallies; or, if the fact to be explained had been the occurrence in the superficial gravel of central England of fragmentary masses derived from the shores of Baffin's Bay, the ice floe hypothesis might have been resorted to with great probability, because, from those frozen coasts, icebergs are every year detached, covered with masses of rock—and they have been met by navigators, drifted, with their load, to more southern latitudes than those of any part of Britain. But the case is widely different when we float boulders upon rafts of ice from regions where icebergs are unknown—and when we are obliged to join Ireland and Scotland to Norway, and to pile Saddleback upon Skidaw, in order to cool our climate down to the freezing point, surely we ought not then to claim the merit of reasoning from *veræ causæ*, though we may not be so prodigal of violence and niggardly of time as the diluvialists, but may modestly limit ourselves in our geological operations to the use of forces not of the same type only but of the same intensity as those which we see in daily action.

But the ice being given, there are formidable objections against the use of it. Two of these have been noticed by Mr. Murchison—the round and water-worn condition of the blocks, and their diminution in size and quantity from north to south, until they pass off into coarse gravel consisting of the same materials, whereas, had they been borne on ice, it is obvious they would have been subject to but little attrition, and the largest fragments would have travelled as far as the smallest. It may be added, that ice would not have drifted from the shores of Cumberland, at all times, and at all seasons. It would have been fixed during the winter, and in motion during the summer, or at the breaking up of the frost. It would either have accumulated annually, if the climate was sufficiently cold, or it would have formed periodically, during winters of unusual severity. In either case, while the ice was fixed, or in the intervals between its formation, deposits of sand, clay, gravel, and shells, would not cease on the bottom of the Straits of Malvern. The boulders would thus be arranged in regular layers, and interstratified with deposits which would be free from them, and these deposits would be of greater thickness if the ice accumulated periodically, than if it was an annual phenomenon. Now nothing can be more opposed to observed facts than this. The boulders are arranged most irregularly, being distributed at all levels, even in the same mound of gravel.

Moreover, if the detritus from Cumberland had been drifted on ice, how does it happen that all the large boulders have taken the direction of the eastern side of the Island of Wales and Siluria, and that none of the icebergs bearing blocks, as big as cottages, of Shapfell granite, or of any other well known rock of Cumberland, have stranded on the coast of Ireland, or have dropped from the melting bergs, on what was then the floor of the ocean out of which the Green Island has since arisen? How is it that none of them have landed on Anglesey, or on the flanks of the Snowdonian chain, which, if Moel Tryfan be a raised beach, must have been equally submerged? We have granitic detritus in Wales, but in small quantities, and of small size, seldom exceeding in magnitude the specimens on the table (3 or 4 inches in diameter). The largest I have ever observed in Wales are on the summit of Moel Tryfan, and do not measure more than 18 inches along their greater axis. They are very rare and of small size in the undulating tract between the mountains and the Menai—they have reached the summit of Moel Tryfan, and are lodged in considerable quantities in gravel and sand, with marine shells on the side exposed to the sea on the north;—they have only partially surmounted its crest, being very rare on its southern slope at 600 feet, while in Nanttli Valley, at its southern base, only 300 feet above the sea, and opening into Caernarvon Bay to the south-west, neither granitic pebbles nor shells are to be found, the detritus being chiefly local, only slightly water-worn, lodged at various heights, and arranged in the most irregular and tumultuous manner. I suspect that few of the granitic pebbles found in Caernarvonshire are natives of Cumberland, but that they have been derived from the western coast of Scotland, and the north-eastern granitic district of Ireland. This is a question for Irish Geologists to determine. Chalk flints, and hard chalk of the county of Antrim, only slightly water-worn, are certainly found in the detrital deposits of

Caernarvonshire; and if any conjecture respecting the granitic pebbles of Moel Tryfan shall be verified, and it shall appear that they also have been derived from the north of Ireland, it will tend much to give unity to the erratic phenomena of a large portion of the northern parts of England and Wales. It will shew, that while a great current has borne the Cumbrian erratics to the south and south-east, the present configuration of the surface having had some influence on it, and having produced minor currents along the existing lines of drainage, but not at the same levels, a parallel current has lodged smaller detritus from Ireland on the northern flanks of the Caernarvonshire chain; the southern side of the same chain, as well as of individual hills on its northern skirts, being almost entirely exempt from the effects of this northern drift, and affording only collections of local detritus. I shall adduce several instances of this when describing the detrital deposits of North Wales.

But after all, unless it can be proved that Lancashire, Cheshire, and Shropshire, formed the bed of a strait of the sea, at the time that the northern drift was deposited, the ice floe hypothesis becomes a piece of machinery as useless as it is cumbersome, because it was only called in to explain the phenomena, by means of forces of the same intensity as those observed to be producing the changes on the surface of the earth now in progress. That the sea has overspread the district at a very recent epoch, is attested by the presence of marine remains of existing species—but if this was only the transient action of the ocean, we are then obliged to explain it by alterations in the relative levels of land and sea,—so much more sudden, violent, and extensive, than any which have occured within the range of human experience, that we are compelled to refer them either to unknown causes, or to causes analogous to those now in action, but differing from them in degree. And such great and sudden oscillations of land and sea, may have been sufficient to transport these huge masses without the aid of ice. I contend that we have not sufficient evidence of the existence of these Straits which have now swallowed up Mr. Murchison's ancient shore of Lancashire, and estuary of the Ribble. The tranquil abode of the sea on the valley of the Severn, within a very recent epoch, rests only on the presence of marine remains of existing species in superficial gravel, unattended by any of those circumstances which are adduced as proofs of the gradual formation of other sea-born strata. The proof of the existence of the eastern shore of this strait is principally deduced from the observations of Mr. H. Strickland, which shew the transport, from east and north-east, of fluviatile and land shells mixed, with the remains of extinct quadrupeds in the banks of coarse gravel following the drainage of the Avon, near its junction with the Severn; and they are supposed to have been deposited at the mouth of a river which had borne them onwards beneath the waters of the adjoining strait. Mr. Strickland's paper on the subject, communicated to the Geological Society of London in December, 1834, is entitled, " An account of land and fresh-water shells found associated with bones of land quadrupeds beneath diluvial gravel at Cropthorn, in Worcestershire." The deposit in which these remains occured is described as consisting of a layer of fine sand, resting upon lias clay, and containing twenty-three species of land and fresh-water shells, two of which are supposed to be extinct, with fragments, more or less rolled, of bones of the *Hippopotamus, Bos, Cervus, Ursus, and Canis.* The sand passes upwards into gravel which extends to the surface, and differs in no respect from the other gravel of the neighbourhood, being composed principally of brown quartz, but occasionally containing chalk flints and fragments of Lias Ammonites and Gryphites. The bones, though most abundant in the sand, are interspersed also through the gravel; but the shells are confined to the sand.. From these phenomena the deposit is supposed, by Mr. Strickland, to be the site of an ancient river bed, rather than of a lake, and to belong to the newer pliocene era.* The imbedded remains undoubtedly indicate a river bed within the area of the supposed Straits of Malvern; but it is difficult to imagine how remains exclusively terrestrial could have been drifted into the sea, and there deposited without any intermixture of marine remains. I have been able to meet with no such separate deposit of the spoils of the land, where any of the rivers of Caernarvonshire enter the Menai. The relations therefore of the northern drift to the fluviatile deposit requires the most rigorous examination. Does the gravel which covers the sand containing mammalian bones, and land and river shells, contain granite fragments? Does it contain calcareous fragments, and are they drilled by lithodomi? Have any of the pebbles or bones Balani or Serpulæ adhering to them? and do marine and fluviatile remains ever occur intermixed or interstratified? These queries must be answered before we can decide that these terrestrial remains have been borne onwards by the river, and deposited beneath the waters of the sea.

The facts relied on by Mr. Murchison to establish the western boundary of these Straits are—

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* Proceedings of the Geological Society. Vol. II. p. 3.

1st.—The local nature of the detritus of the region of south Wales and Siluria, which is stated to be all derived from the hills of the immediate neighbourhood, the materials changing in the vallies of the Teme, Onny, Lug, and Wye, with each successive ridge they traverse, and the large fragments being transported only short distances.

2nd.—The direction in which the detritus is distributed, which is so extensively spread over vallies, slopes, and, sometimes, on high situations, depends on the strike and dip of the strata, being to the south-east when the dip is south-east, and north-west when the dip is in that direction. Mr. Murchison, therefore, supposes these detrital masses to have been formed beneath the sea, either in its gulphs, estuaries, or straits, and to have been raised up at different periods, when the solid strata were elevated; and he specially distinguishes them from the detritus carried down by rivers, under the atmosphere.

3rd.—Not a fragment of the northern detritus enters the region of Welch and Silurian drift.

4th.—Certain mounds, near Shrewsbury, consisting of Silurian drift, are capped by northern drift. On this I must remark that if the drift of Siluria had been formed under the sea, either in bays, straits, or estuaries, and had subsequently been elevated to its present situations, it is very singular that it does not manifest the same proofs of its submarine origion as the northern drift, which is supposed to have been formed in the same manner. The one is considered of marine origin, because it contains marine shells—the other, because it contains none. If the drift of Siluria were formed under the sea, at different epochs, how is it that we cannot distinguish those epochs by their peculiar organic remains?

The absence, moreover, of granitic detritus, aad of shells, from the region of south Wales and Siluria, is negative evidence on which much reliance can not be placed. Between the Menai and the summit of Moel Tryfan, Section III., we have a district comprising, at least, seventy square miles which, because it is now known to afford, at intervals, shells of existing species and granitic detritus, Mr. Murchison, and some other geologists, would consider to have lain quietly under the sea while the northern drift was forming on the eastern side of the mountains of Wales; and yet, on nearly the same evidence as that adduced by Mr. Murchison in the case of Siluria, it might, a few years ago, have been pronounced to have been elevated above the sea before the northern drift took place, for throughout this whole area, the detritus is chiefly local; it has descended from the mountains of Snowdonia by the lines ot existing drainage, though at higher levels—foreign detritus has only been detected in it at eight points, and marine shells at four—and in all these cases, except two, they have been brought to light accidently by means of excavations made in working slate quarries or forming railways, and sections made only a few yards to the right or left would have failed to discover them. When I shall hereafter describe the detrital deposits of the western side of the Cambrian Chain, I shall shew that granitic fragments and broken marine shells are only found, within this district, in situations exposed to the sea *on the north*—and that in situations protected on the north by high mountains, cliffs of detrital matter contain only local fragments partially water-worn, and that marine remains are, in such cases, absent even where the base of such cliffs is washed by the waves of Cardigan Bay. I shall likewise adduce cases in which an ancient talus of angular fragments of the rock immediately subjacent, forming a breccia *en place* is interposed between the rock and masses of northern detritus, from 60 to 100 feet thick, containing fragments of shells. These cases of breccia *en place* under northern drift with shells, occur, on the southern sides of headlands, in the narrow promontory of Caernarvonshire, but they have not ranges of high mountains protecting them on the north. I shall also be able to prove that they are older than the northern drift, and have not been formed subsequently by movements of elevations, as some, who have never seen them, are disposed to contend.

I shall likewise shew that recent excavations on Moel Tryfan have proved that its gravel containing broken marine shells and granitic detritus—the raised beach of some geologists—rests on rock—not worn in hollows by the action of the breakers—not covered with adhering Balani—but having a layer of its own angular detritus interposed between it and the shelly gravel; while scarcely 1,500 yards to the south-west of this spot, two other excavations have exposed masses from 20 to 30 feet thick, consisting of angular fragments of the rock immediately subjacent—roofing slates in the one case, greywacke sandstone in the other. One of these accumulations of detritus is covered by about five feet of loam and gravel, with boulders, partially water-worn, of rocks derived from no great distance—and to prove that the angular and partially water-worn detritus are nearly contemporaneous, two or three of the boulders are mixed up with the anguler fragments. I can explain these phenomena, on the supposition of a violent rush from the north, respecting in some degree the existing configuration of the surface,—but I cannot explain them on the hypothesis of long submergence; and I would suggest that perhaps the phenomena of local detritus in south Wales and Siluria may admit of a similar explanation.

ON THE LIMESTONE OF THE COUNTY OF WEXFORD.

BY CHARLES W. HAMILTON, ESQ., F.G.S., M.R.I.A.

At a former meeting of this Society, I undertook to visit the district of Hook in the county of Wexford, and report to the Society upon the nature of the limestone which forms the extremity of that long promontory. I took the earliest opportunity of doing so, and the result has been an impression upon my own mind, of the *probability* that further researches may enable us to separate it from the great central bed of mountain limestone, and call it the lower member, with as much reason as Mr. Phillips has partitioned off the upper or Enniskillen beds; but the sphere of my observations has been as yet so very limited, that I wish to be understood as not attempting to prove this to be the case, but merely throwing out the idea as a subject deserving of further inquiry.

The district which I examined, extends from Duncannon Fort on the Suir, and Fethard on the sea coast to Hook Head; the rocks do not appear to me to be anywhere visible inland, but the cliffs which are from one to 200 feet high in the northern portions, and every where greatly exposed, present a very beautiful section. The general succession has been described by Mr. Weaver. The clayslate extends southerly as far as Carnyven Headland on the East; and the valley which runs from Templetown church to the sea on the West. The general direction is about N. E. by E. and S. W. by W. it is so twisted in the line of stratification, that it is difficult to say what the dip is, but I believe that it may be stated as being generally to the North, and at a very high angle. The rock is composed of layers of about one-fourth inch in thickness, of a dark and light colour alternating, and this striped character connected with the grotesque contortions, and the numerous caverns produced by the action of the waves, gives all that shore a very interesting appearance.

The clayslate supports a red sandstone conglomerate, which is in several distinct masses; one of these occupies the banks of the Suir, from Buttermilk Castle, on the North, to Arthurstown, (here it runs for a considerable distance nearly horizontal, but is tilted up at the north and south junctions, with the clayslate in opposite directions. Another detached mass forms the elevated headland of Broomhill. Mr. Weaver has described it as capping this hill, but in fact. it forms the whole of it. We next meet a broad band of this conglomerate stretching across the whole promontory, lying unconformably upon the clayslate, and supporting conformably the limestone.

Where it is in junction with the clayslate, it appears to be much broken, and on the eastern shore there is one very evident fault, of ten or fifteen feet; but the slate is so broken that a mass of clay and angular fragments of many feet probably 30 or 40, lies between the solid part of both rocks to the north of Broomhill. This debris forms a bed of about 30 feet thickness, and has almost the consistency of a Breccia; the fragments cross each other in every direction; the conglomerate consists of beds of considerable thickness, alternating with each other, of fine red sandstone and a coarse conglomerate, containing pebbles of coarse clayslate and quartz. In the inferior beds the pebbles are sometimes as large as one's head; as we ascend they appear to diminish in size; near the junction with the limestone there occur beds of a very variable character, some of them grey and highly micaceous; others again of a close texture and extremely hard. Within a few yards of the junction of the limestone I observed on the west shore, a succession, consisting of 1 conglomerate, 2 hard siliceous sandstones containing abundance of encrinal remains, 3 conglomerate, 4 limestone; of these I have laid specimens upon the table. The dip of the conglomerate varies from 2° or 3° to 15° to the S. E. The limestone extends from the cross roads near the Old Castle, at Houseland, to the Tower of Hook, a distance of about two miles; but the longest line in the direction of the dip is about seven furlongs. The beds appear to underlie each other regularly, without any interruption, dipping upon an average about 30° to S. E.; the only place where there is any appearance of contortion is at the Tower of Hook; where the strata dip to the north west; the beds range from a few inches to two feet in thickness; and the total depth may be calculated at about 1700 feet as far as the incorrectness of the present map will allow of our approximation to the truth; the character of the rock is remarkably homogenous, of a dark colour and unmixed with beds of slate; it is extremely hard, and does not disclose any trace of its animal composition, except where weather and water-worn; but an examination of the exposed faces and sides, proves that the whole of this immense thickness is one consolidated mass of the remains of encrinites, to which the other fossils which are scattered through it, although more conspicuous, bear but a small proportion.

It is not easy upon so rugged and indented a shore to measure distances, with even accurate eye-measurement; but as to the distribution of the fossils, I think I may venture upon dividing the whole into three parts; those which are common to all three, and form in fact as I before stated the mass of the rock, are:

Actinocrinites levis, Cellepora Urii,
Retepora Elongata, Turbinolia Fungites,

and perhaps some other minute Zoophytes.

In the upper portion the number of bivalve shells appears to be very small, those of which I lay specimens on the table are probably the

Spirifer Crenestrea,
do. Attenuata,
And the Cypricardia Glabrata of Phillips.

I found also in this portion the claw and two of its articulations of a crustaceous decapode; this is worthy of remark as I do not know of any other instance being recorded of such having been found in the carboniferous limestone.

The middle portion is characterised by a great abundance of coral of two species, Syringopora Ramulosa, which also occurs sparingly in the lower beds, and Manon Favosum of Goldfuss, which I found only in the central portion. Goldfuss considers this coral as the foundation of Cyathophyllum quadrigenimum, to which he would probably refer some of the specimens before you; it is the Favosites Quadrigeminum of De Blainville.

In this portion I found that remarkable shell, which occurs in such abundance in the Malahide limestone; and of which Dr. Scouler will give a description.

The characteristic of the lower portions is a greater abundance of bivalve shells, apparently Spirifers and Terebratulæ, and it is difficult to distinguish species, as they are only observable in the waterworn sections, and cannot be detached, but I could not observe any that I would refer to the genus Producta.

I shall now venture to compare these with some beds of limestone lying in the immediate neighbourhood of Dublin, and which I do not think have as yet been studied with the attention which they deserve; they are exposed along the sea shore from the north extremity of the Portmarnock or velvet strand as far as the village of Malahide. Although there are some slight undulations the general dip may be stated as being to the north, sometimes varying 10 or 15° to the west of north. This limestone bears the closest resemblance to that which I have just described, it is, like that, a mass of encrinal remains, the species apparently identical; the lithological character is the same and the fossils do not show themselves except where the decomposition of the surface displays them in a beautiful relief. The principal difference is, that the beds of limestone sometimes contain pebbles of the same character, and are interstratified with thick beds of shale consisting wholly of encrinite; among the fossils of the middle beds are to be seen specimens of Orthoceros and Euomphalus. When we ascend higher up in the series, we find the same abundance of Syringopora Ramulosa and its attached companion the bivalve before alluded to. In none of these beds have I been able to see any trace of Producta, that shell which has been hitherto considered the characteristic of the mountain limestone.

When we arrive at the shore of Malahide bay, the limestone continues to dip to the north; but the sea and the sandhills upon the opposite shore forbid a further pursuit of the ascending series in that direction, and indeed it is probably soon interrupted, as the traps and calcareous conglomerate of the Portrane shore seem to have a general tendency to dip to the south.

But by retracing our steps, and resuming the inquiry on the flank of the beds first described, we find the rock of Carrick consisting of encrinal limestone, only differing in colour, and in a greater degree of chrystallization from that of the seacoast which evidently underlies it. Again the Hill of Malahide, apparently of the same character, and here again our progress being obstructed, obliges us to return to the well known quarries of St. Doulaghs and Feltrim, which were taken as the earliest types of the Irish limestone; here we find a great difference in the lithological character of the rock. The fossils are easily detached from the general mass, and though still Encrinites Retepora, &c. form the base; yet the abundance of Producta, Isocardia, Nautilus, &c. appears to me to separate it very clearly from the lower beds.

I shall now merely refer to one more locality, that of the Kildare Hills; where the limestone which is there upheaved and altered by the contact of Trap, appears to resemble very closely the Wexford and Malahide beds; there is a plicated character which seems to belong to the Terebratulæ of these inferior portions, and looks as if it might possibly connect them with their congeners of the silurian and older rocks, and is deserving of accurate attention.

ON THE MECHANISM OF GLACIERS, BEING AN ATTEMPT TO ASCERTAIN THE CAUSES AND EFFECTS OF THEIR PECULIAR, AND IN PART, UNOBSERVED MOTIONS.

BY ROBERT MALLET, B.A. T.C.D. M.R.I.A.

THERE is perhaps not one amongst the grander objects which nature presents to our view, so difficult to be described, or a clear impression of its general aspect and gigantic proportions conveyed, to one who has not had the advantage of personal inspection of these sublime masses, as a glacier. The appearance of tumultuous and broken, and ever changing masses of ice, differing in substance from the ice we are in the habit of observing, and spreading over a wide and declivous expanse, in some cases nearly equal in area to one of the smaller counties of England, is so far removed from any of the objects that are familiar to us, that no adequate conception can be formed of them but by actual view.

But although it would be for these reasons useless, and be beside the purpose of the present paper, to enter into any lengthened description of the appearance, and visible phenomena of glaciers, it is yet possible to convey distinct notions, of the agencies employed in their formation and motions, together with their mutual balance and dependance.

The object now is, to endeavour to show, that although much has been written on the subject of glaciers by Merian, Simler, Höttinger, Scheuchzer, Saussure, Grüner and Playfair, yet that the great and important forces concerned in their motions and forms, and by consequence in their increase and decrease, have been wholly overlooked, undiscovered, or misunderstood.

The originating causes, even of the formation or deposition of glaciers have been matter of dispute. In the Journal de Physique for 1779, a theory is to be found which assigns their production in their beds to congelation of the snow water from above, there can be however no doubt, but that, upon this point the prevailing notion is correct, which briefly stated, considers their formation to have proceeded thus. The clouds supply the mountain summits with snow, &c. resting on them, at all times down to the snow line, the avalanches from these falling into the transverse Alpine vallies, and occasionally into the heads of main or *grand trunk vallies*, supply snow and water together, which by a gradual process of consolidation and crystallization, assume the form of the rough ice of the glaciers, while these latter again, in dissolving, become the parents of rivers; and as we proceed, we shall find that the great causes producing the descent and dissolution of glaciers are the same as those concerned in the debacle of frozen rivers. But as it would be impossible within the limits necessary to be now observed, to enter fully into all the varied conditions which a full discussion of these would involve; I purpose, at present, chiefly to consider.

1st.—The forces producing the descending or precessional motion of glaciers, or what may be called their *great motion of translation.*

2nd.—The causes of the *vast rifts or crevices* which traverse them, and of their peculiar, and most remarkable lines of direction.

3rd.—The causes and effects of the peculiar arrangement, observed in the *Moraine* or stony debris, which covers large tracts of their icy surface.

4th.—And lastly, to consider the causes of some of the *contingent* but not less singular *phenomena*, that are occasionally or periodically observed, in connection with all these bodies.

As to the first, namely the cause of their great motion downwards, towards, and into the Alpine vallies, every author upon the subject, down to the most recent, has given no farther solution, nor apparently conceived any further account necessary of it, than that the enormous *weight* of the glacier itself resting on an inclined bed, and of the vast masses of snow in the higher regions, bearing on *it*, forced or drove it forward gradually, by the mere force of gravitation.

Although the circumstance of such stupendous masses having a more or less regular annual motion of many feet, would seem to have been one capable of commanding a careful and precise investigation, yet such we find to be the account given by Saussure, and the other authors quoted, (so far as I have been enabled to refer to their works,) and more recently by Playfair, by the author of the article glaciers in Brewster's Encyclopædia, and of the corresponding one in the Dictionaire des Sciences Naturelles; so Dr. Prout in his Bridgewater Treatise, gives the same solution, he says, "the glaciers accumulating in the vallies, are often by the enormous and increasing *weight* of the snow and ice in the upper parts, *pressed* downwards far beyond the limits of the snow itself."

Playfair's notion of the subject is the same, merely adding that the surface of the ice is loaded with a great weight of stones.

Now I would at once say that this view is utterly insufficient to account for the great motion of translation of glaciers, which sometimes amounts to twenty-five feet in a year, and is seldom less than ten feet per annum. For the beds of rock on which they rest are in general the ends or crop of upheaved strata, and are always more or less rugged and uneven, and hence the resistances from friction, &c. enormous—these beds have seldom a steeper inclination, taking it from the upper surface of the ice, with large allowance, than 25° to 35° at a maximum, while those on which the supereminent fields of snow rest above have rarely more than 35° to 45° of inclination—indeed at much steeper than this the snow will not lie at all, so that, by mechanics, we perceive but a small portion of the total weight of either can be resolved in a direction parallel to the inclined plain so as to produce progressive motion—and further from the direction in which the pressure of the upper fields of snow parallel to *theirs* beds is transferred to the lower masses of ice at a different inclination, a still further portion of this force is lost, thus twice resolved to produce motion.

As it is extremely probable that the friction of a glacier, *even if resting on a perfect plain* of gneiss, or granite, would be equal at least to one half of its weight, it is obvious that this alone would prevent its motion of translation on some of the above declivities—but, added to this, it always happens that the bed of the glacier contains large depressions to which the glacier assimilating itself becomes *hooked* as it were to its bed, so that it cannot slide without either breaking these detents, or being lifted out of these cavities.

The great "primum mobile" then which causes these collossal masses to advance with such steady and irresistible force is not to be sought in their weight alone—and my first object is to show that it will be found in *hydrostatic pressure*, acting between these masses of ice and the rocky bed on which they rest, and thus *at intervals lifting them up and floating them, or as it were transferring them upon liquid rollers from a higher to a lower level.*

It will be recollected that from the nature of the Isogeothermal curves, the bed on which a glacier rests is warmer than the ice of the latter, hence a process of melting from below is perpetually going on winter and summer, giving birth to those torrents which rush forth from the lower terminus of every glacier.

This melting, by conduction and radiation from below, is altogether independant of season, and in a great degree even of climate, while the superficial melting above depends wholly upon these—hence, in summer, when the icy surface of the glacier is denuded of snow, and all in slow process of liquifaction, and the streams and torrents are full and running, the waters produced find a ready vent below; and but for the aid of *certain casual disturbing forces*, to be again alluded to, the glacier, in summer, would not advance at all—but when winter has covered its whole expanse many feet deep in snow, and when the embouchure of the subglacial streams is also gelid, and partially, or sometimes, wholly stopped, the waters rising and pent up beneath the bed of the glacier lift its mass more or less from off the base on which it rest, and with more or less regularity according to the variety and size of the several segments into which it is divided by the crevices, until at length a sufficient change of position is effected to permit the escape of the imprisoned waters, when these rushing forth, empty the icy caverns which they had filled, and the mass of the glacier, whole or in parts, descends by a certain distance into the valley. The motion cannot hence, be uniform but "per saltum," which is found to be the general fact, though often difficult of observation.

A most remarkable instance of this occured in the year 1814, or rather in the beginning of 1815, in the "Glacier de Bois," generally known by the name of the "Mer de Glace:" The Arveyron, the torrent which had hitherto rushed from a vast icy vault in its base, or from beneath the stupendous talus which then and now forms its termination in the Valley of Chamouni, became stopped below, partly by the falling in of masses of ice from the crown of the arch, and partly by being frozen up; the waters rose beneath the ice, and at length, at a height of 700 feet above the former embouchure, opened a new passage for themselves, and now fell into the valley in a great cataract, over rocks of ice, instead of as before discharging at the level of the very bottom of the valley. The pressure in this case, which must have been above 300 pounds upon the square inch at the lowest part of the ice, became so enormous that for some months the fall of stupendous blocks or mountains of ice from the lower end of the glacier into the valley was almost continual, tearing up and burying the sunny meadows at its base, and mowing down the crashing pine forests that stood in the path of these resistless projectiles.

Two remarkable instances of similar phenomena are recorded in the Journal of the Royal institution: "The glacier of Ostler, in the vicinity of Chiavenna, in the Tyrol has, notwithstanding the late moderate winter, (viz. of 1817) increased in a very extraordinary degree—a stream which formerly ran from this glacier has ceased to flow since Michaelmas, 1817—and incessant subterraneous noises and roarings which are heard from beneath the ice, are attributed to the collection of waters within the glacier."

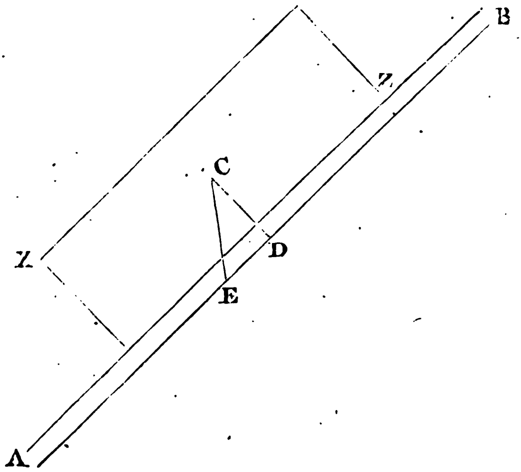
The glacier in the Valley of Nandersberg has presented similar appearances; and great fears are entertained for the neighbouring country in both these places, on the liberation of the confined waters on the approach of summer."—Journal of the Royal Institution, 1818. Vol. V. p. 134.

The other instance is as follows :—" On the 27th of December, 1819, at six o'clock in the morning, an enormous portion of the glacier of the Weisshorn, in the Valley of St. Nicholas or Vispach, fell from its exalted situation into the valley, causing dreadful devastation in the cultivated grounds and habitations."

" At the moment when the ice and snow struck the masses lieing beneath, the minister of the place, and many others, observed a *strong light*, which immediately disappeared and gave place to utter darkness. This phenomenon, from the brightness of the light and the number of persons who saw it, can scarcely be considered illusory. It was probably an electrical, or phosphorescent effect. The mass of ice and snow covered a space 2400 feet in length, 1000 feet in width, and at a mean 150 feet in depth—and the displacement of the air was such, as to cause a hurricane, which destroyed houses, mills, and buildings, even at a quarter of a league from the place of the fall. Extreme fears are entertained for the remains of the Village of Ronds, which stands opposite the glacier—for the upper part, left unsupported by that which has given way, threatens to fall, and complete the distress it has brought on the inhabitants of the valley."—Journal of the Royal Institution, 1819. Vol. IX, p. 426.

Here then are three " crucial instances," all depending on the same causes, and all taking place in the winter frosts—and as we shall have occasion again to refer to in winters of unusual severity.

When a glacier then; assumed in its simplest condition, namely, as consisting of a single mass, or without crevices, is lifted from its bed, by hydrostatic pressure produced by its subglacial waters, it is clear that it is raised in a direction *perpendicular to its bed*, that is, to the surfaces pressed, but when by the withdrawal of the waters, it is again deposited; it is equally clear, that it will sink in a direction *perpendicular to the horizon*, and hence the immediate cause of the progressive descent, or great motion of translation. This will be rendered familiar by Figure 1, where A. B. is the bed on which the



glacier rests; X Z a mass supposed to represent the latter. Then if a fluid press between the surface A B and that of the mass in contact with; motion, if produced, will be in the line D C; and if the fluid be now withdrawn, and the mass be unsupported below, it will fall in the direction of the vertical line C E, by which a movement down the inclined plane B A, equal to the distance D E, will have been effected. Here these two motions are supposed to act consecutively—but it is obvious they may act simultaneously or have a resultant, as in all probability, is in most cases the actual fact.

Most of the Alpine glaciers have an average depth of above one hundred feet, and some are said to have a local depth of three times that amount, while crevices have been measured of six hundred feet in depth; hence we can easily conceive the prodigious hydrostatic pressure produced by a column of water of such an altitude, filling one or more of the crevices in the icy mass, (whether it be large or small it matters not) when multiplied into the great base upon which it acts. And it is further observable, that as the specific gravity of ice, even in its most solid form (and that of the glacier is far from solid) is less than that of water—*there is no depth of a glacier, however great, which can prevent its being lifted from its bed by the waters beneath its own base.**

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* The specific gravity of fresh-water ice, varies from 0,800 to 0,950. The latter

This then I consider the true prime mover or great [illegible]ting force of glaciers. Hydrostatic pressure, having its origin in difference of temperature, which in fact appears to be the great "primum mobile" of nearly all the geologic changes, great or small, that affect our earth.* Figures 2 and 3 are respectively a longitudinal and transverse section of a glacier in summer—and though necessarily distorted as to proportion, and otherwise imperfect, will serve to convey a clear idea of the action of the forces we now treat of and shall have to consider.

In figure 2 the rock is observed in section, forming the bed on which the glacier rests. AA above it is the mass of the glacier BB also in section—and above its upper surface will be seen the irregular outline of the Moraine which covers part of it, marked CCC, &c.

The upper part of the glacier ice vanishes into the perpetual snow at DD.

It will be seen that the nether surface of the ice is only in contact with the rock or bed at certain points of support—the space intervening being produced by the melting from beneath—and in which the subglacial torrents are shown discharging themselves from beneath the arch at the lower end of the glacier. Figure 3, is a transverse section of the same glacier—the same letters refer to both figures, The upper surface of the glacier is seen in figure 3 stretching away towards the snow line, and is intended to give some idea of the general disposition of the crevices and Moraine.

The more minute features of these figures we will recur to further on.

We have next to consider the forces in action to produce those vast rifts or crevices, which traverse and dissect the bodies of the glaciers. With many slight perturbations, de-

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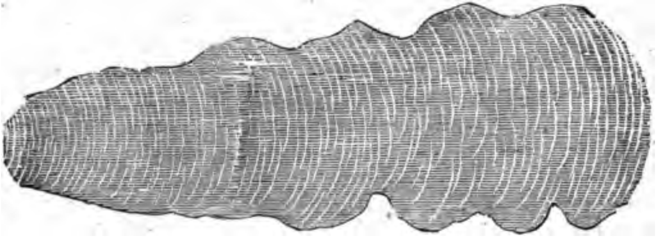
and highest determination is by Roger and Dumas, but was probably made in reference to water at 60° Fahrenheit, and on the densest possible specimens.

The pressure of a column of water of 600 feet in height is about = 18 tons per square foot, or about 27½ millions of tons to a square mile with water at 60° Fahrenheit—of course it is somewhat greater with water at or below 32° Fahrenheit.

* In claiming for myself to be the first proposer of this new doctrine, it is due to Saussure and Playfair, as well as to myself, to state that they both *incidentally* notice the fact of the melting of the glacier ice from beneath; and the former gives it as his opinion, that it is even possible the ice might be *lifted suddenly* (soulever) by the water so produced; but neither drew any conclusion from their observation, nor seemed to consider the facts of any importance to a general theory of glacier motions—indeed Playfair is express in ascribing their descent to *weight alone*. In his Illustrations of the Huttonian Theory (Vol. I. p. 284. Works, Edinburgh, 1822.) he says, "These great masses are in perpetual motion, undermined by the influx of heat from the earth, and impelled down the declivities on which the rest by *their own enormous weight*, together with that of the innumerable fragments of rock with which they are loaded.

pending chiefly upon the amount of declivity of the bed of the glacier, these crevices have a great general direction, transverse to the line of motion of the glacier, or accross the valley in which the glacier lies. Their general form, as shown in plan in figure 4; is that of a curve, or vast wave-like line,

Figure 4.



crossing the ice from side to side, and having its convex side presented downwards, or towards the direction of motion of the glacier—a form which has suggested Coleridge's poetic description of these sublime objects:

> "Ye Icefalls! ye, that from the mountain's brow,
> Adown enormous ravines, slope amain—
> Torrents, methinks, that heard a mighty voice,
> And stopped; at once, amid their maddest plunge;
> Motionless torrents—silent cataracts!"

Cross fissures, that is, crevices crossing the former ones at an angle, and whose direction hence approaches that of the axis, or line of translation of the glacier, are comparatively rare, and, as we shall see from the form of the bed of the glacier, as in figure 3, have a constant tendency to close in at the top, and so become obliterated.

The original formation of a glacier, being the deposition of a bed of indurated snow in the bottom of a sloping valley, becoming surcharged with infiltrated water, partly produced by rain, and dews, and partly by its own liquifaction, must be presumed to have originally formed one unbroken mass, beneath which a current of ice water flowed out, then, as now; but no sooner had the first obstruction from frost or debris, stopped the course of its subglacial stream, than the waters began to rise beneath its bed, until at length, the hydrostatic pressure, accumulated at its lower end, overcame the cohesion of the ice, somewhere, above or below the upper line of the subglacial waters, and the huge mass broke into two or more parts, as a vessel in standing, by resting on a single point, or supported only at stem and stern, becomes "hogged or breaks her shear," as it is technically called. This process endlessly repeated, united with the various minor and contingent, but still related forces, of one broken mass staggering against another, rocks falling in and getting nipped between them, and some of the masses from their accidental form, wedging up and lifting out upon the surface of the glacier, other interposed pieces, and thus forming the "Hummocks" so often seen, will account for that strange and capriciously varied surface, which constitutes much of the novelty and singularity of the aspect of a glacier.

These operations are most evident, when the inclination of the bed of the glacier is greatest, and in some cases where this is excessive, become the principal phenomena, as in one of the lateral, or branch glaciers of "De Bois," called "Le Telefre," the steepness of which is such, as to have deprived it of all semblance of a uniform surface. It consists entirely of an impassible mountain mass of pyramids and blocks of ice of collossal dimensions, tumbling at intervals over and over, and grinding each other to fragments in their headlong course.

Some of these varied secondary forces of division, however are too interesting and too immediately connected with the present part of our subject to remain unnoticed.

When an isolated rock or stone, rests upon the surface of the solid ice, it may be near the center of one of the crevice-surrounded masses, where some "emboulment" has deposited it, by its greater conducting power and heat absorbing surface, it becomes warmed by the sun's rays, much more than the ice on which it rests, and sinks down through the substance of the ice, forming a tube of its own diameter, often of an enormous depth. For although the sun's rays cannot reach the stone directly after the depth of the tube has become equal to its diameter, multiplied by the tangent of the suns meridian altitude, and then but for a short time in the day, yet it continues long after to reach it, by one or several reflections, from the glassy sides of the tube, though of course with diminished energy.

It is probable that all these tubes are the work of a single summer, and are all frozen every winter, and there is no doubt, but that the larger ones are often greatly deepened and enlarged, by the flowing into them of the ice water, from the surface of the glacier, which, being denser than the water in the tube which is at 32° Fahrenheit, falls to the bottom and heats the stone, while the colder and less dense water flow off at the top of the tube. This although apparently analogous, will be observed to be a totally different case from that proposed as a solution of the formation of these tubes, given by

Count Rumford, and yet to be noticed. There was one on the glacier de Bois, in the year 1831, of about 3 feet in diameter, which was 70 feet in depth.

This tube, by the melting of the ice of its sides, gets gradually enlarged, and filled with water, until at length the enormous lateral Hydrostatic pressure produced by the fluid column, overcomes the cohesion of the ice, and as it were by a sort of natural blasting, the mass is split into two or more seperate pieces, and thus in every part of the glacier, the process of subdivision goes on.

Figure 5 gives a clear conception of this process seen in section. These tubes are at first all necessarily bored perfectly vertical, but if it happen that after a stone has gone to a certain depth, the block of ice in which it rests, has changed its position, so as to throw the tube out of plumb, as seen at K. so that the suns rays can no longer enter, it sooner or later gets frozen up again and lost. Sometimes these tubes burst out of the sides of crevices, and become the descending ducts of cascades, by which they are rapidly enlarged at as M. In the case shown at K. they become natural plumblines to determine the change of position with respect to the horizon which a block or a district of ice may have sustained.

In the formation of these tubes, there is little or none of the heat absorbed by the stone during the day, lost by radiation upward during the night, for although during the day, the water in the tube remains clear and permeable to the suns rays; soon after sun set, a thin sheet of ice forms on its surface, in each tube, and by its want of Homogeneiety, screens off all upward radiation, so that all the heat the stone receives, is given out to the ice.

Count Rumford proposed a different hypothesis to account for these tubes to that here given, in the Philosophical Transactions for 1804, p. 23. He supposes that as the water in these tubes from contact must be at the temperature of the ice, 32° Fahrenheit, the warm winds of summer passing over the glacier, warm the water at the surface of these tubes slightly, by which its density being *increased*, until it reaches 40° Fahrenheit, it sinks to the bottom and melts a portion of the ice there, but he seems to have wholly overlooked the existence of the *stone* in the bottom of *every tube*, and would find it hard to show an adequate cause for a beginning to any one tube on his hypothesis, but admitting his view as a "vera causa," it is altogether insufficient to account for the magnitude of the observed results, which require forces of a far steadier and more powerful kind to produce them. It is however evident from his *having* overlooked the stones in the bottoms of the tubes, and described them *all* as of about four feet deep, and seven inches diameter, that Rumford gave them but a very superficial consideration.

The splitting of the ice produced by these *pressure tubes*, as they may be called, must take place suddenly, but there are also numerous instances on record, *of large tracts of glacier ice* being instantaneously split up and rent in a terrific manner, accompanied by loud explosions.

To produce these effects, many causes may conspire, two however are especially worthy of notice, as following from the conclusions already arrived at, and observed facts.

1st.—The partial or total *sudden* stoppage of a subglacial duct, by ice or masses of rock, which may either fall from the under surface of the ice, or through a crevice, or by masses of rounded rock rolling along the subglacial streams, and suddenly arrested at some narrow gorge, thus acting as a valve more or less perfect.

In such a case, the walls or sides, and roof of the icy tube, which had before sustained a pressure from the running waters approximating merely to that due to the entire head of water, minus that competent to produce the velocity of the stream at the point of stoppage, are instantaneously exposed to a pressure vastly greater than that due to the total head of running water, and as the *whole column* of flowing water is arrested at the same moment, this enormously increased pressure partakes of the nature of a *percussive force*, so that the united energies of these are capable of rending masses of ice, whose cohesion would resist much more dead pressure than the whole altitude of the subglacial column possibly could supply. This operation has throughout a strict analogy with the action of the machine, called by its inventor Montgolfier, Le Belier Hydraulique, or Hydraulic ram.

2nd.—From the small *range* of elasticity of both ice and water, the foregoing phenomena, though capable of the *disruption* of enormous masses, can effect their *translation* to but very small distances, but when the form of the subglacial tubes is such, that large caverns are locally formed in them, so that *air* can lodge in them, the case is altered.

The included air in such a predicament, is compressed to a density due to the pressing head of water, but if the flow of water through this *air vessel*, be suddenly arrested, as in the former case, all the consequences before described follow, but with this important difference, that whereas in the former case, each riven block of ice was probably moved but a few inches, in the latter, the icy masses are upheaved, as if by an exploded mine, and attended by the escape of gusts of wind, let loose with explosive violence. The difference, is due to that of the *elastic range* of water and ice on the one hand, and air on the other, and may be illustrated by the method adopted for proving cannon, namely, by forcing water into them, (when closed in all directions) by a very small pump, if under this immense hydrostatic pressure, the gun burst, its fragments fall harmlessly asunder, but if some air be included along with the water, and the piece burst, although, at the very *same* pressure as before, the fragments are projected to considerable distances, as if it had been torn by gunpowder.

It is to be observed also, that the air of these icy caverns is frequently *sent down into them in a highly condensed* state.

This singular circumstance arises from accidental causes, producing cascades of water from streams on the upper surface of the glacier, down through crevices or through presssure tubes which have perforated the ice quite through into the streams and caverns beneath. These cascades carry down with them an immense volume of air, on the principle of the well known ancient Italian blowing engine, called the "Trompe," so that this air arrives at any cavern under the ice, suitable for its retention, already in a highly condensed state. By connecting then these two last described phenomena, the causes of those sudden and tremendous *icequakes*, as they have been called, and also of those intermittent, or often constant currents of air found rushing up out of cavities, in glaciers will be fully understood, and the mystery with which they have been regarded, resolved altogether.

Figure 6. Is a section so far as the upper part of it is concerned, of one of these cascades which I found on the Mer de Glace in 1831, it fell into an aperture of about eight feet in diameter, and the body of water was such as not only to have deeply undermined the sides, but falling with stunning violence into the abyss, it carried down such a volume of air, as made the mouth of the pit dangerous of approach; by its reverberations even where the ice was solid. The lower part of the figure shows the structure of an imaginary air vault. Such are the causes producing the fissures or crevices, now, as to the cause of their *general curvilinear direction pointing downwards.*

As the rate of translation of any part of the glacier, will depend upon the height to which it is lifted hydrostatically at this point, and upon the rate at which its nether surface is degraded by the heat of its bed, so the central portions of the glacier will descend towards the valley, much more rapidly than the lateral ones, for all the minor currents of water produced by the melting of the ice below, at every point will coalesce with the main central streams towards the centre of the bed of the glacier, being the lowest part of its sloping surface; hence as every portion of the glacier descends in a line of direction perpendicular to the horizon, and as the central portions of any given mass descend the oftenest and the most, the whole of the crevices surrounding these masses, must assume the form of curves, with their convex side pointing downwards or towards the valley, this will be quite evident on examination of Figures 3 and 4.

I am not aware, nor do I believe, that hitherto, any solution whatever, has been given or attempted by any writer of the peculiar direction of these lines of fracture.

The last branch of the subject which remains to be noticed, is the peculiar arrangement observed of those vast accumulations of stony debris, denominated "Moraines," or "Goufferelines," which are to be found on all the glaciers, but are no where so abundant and remarkable as on the glacier of "Rosboden," on the Simplon.

These are formed of huge masses of loose material, which have a general direction parallel with the line of motion of the glacier, and consequently cross the ice crevices more or less obliquely, as may be distinctly seen in the transverse section, Figure 3, they are often many miles in length, and from 20 to 100 feet in height. Their general form and section will best be shown by the annexed Figures 11, 12, 13, 14, and 15, which are intended to show the progress of the Moraine, (per saltum of course) towards the centre of the glacier, from the period of its first deposition. The material of these almost mountain masses, consists of rolled rocks, boulders of all dimensions, pebbles and crystals, with various minerals, &c. &c. from the high peaks above, and the flanks of the glacier, imbedded in and mixed with a very large proportion of finely comminuted matter of these same materials, much of which is reduced to the consistence of *mud*, and is occasionally found mixed with alluvial earth, where such occurs on the flanks of the glacier.

These are the sources of that exquisitely divided silicious matter, which is carried along by so many of the Alpine torrents, after they leave the glaciers, to vast distances, producing that singular milkiness of colour so often observed; they are also the original repositories of the gold found in the bed of the Arveiron and other similar streams, and in all probability of the grains of platina stated to have been found in the Rhine. On the average, these masses of Moraine do not cover more than, probably, one-fiftieth of the surface of the ice, but cases are found of which Saussure mentions one in which they are so close as to hide the ice altogether. The mountains and naked precipices which flank the glacier vallies are in a continual process of degradation, producing frequent "*eboulments*" or discharges of gravel and stones, and sometimes earth:—hence, when the winter's snows set in, and the number of the "eboulments" are increased by the splitting frost, the whole deposit of snow becomes mixed according as it falls, or at every depth, with gravel and rocks, &c., when the approach of summer partially thaws the winter's snows from off the surface of the glacier, and either denudes again the ice or forms a fresh stratum on its former surface, all this matter suspended or disseminated previously in the snow is deposited on this surface; but as the rapidity of liquifaction is always in spring such, that prodigious torrents sweep over the surface of the ice and form for themselves various channels and runnels, sometimes on the surface, and sometimes through the crevices and into the other currents beneath, so the "Moraine" is swept into the lines of direction of these torrents, and thus are formed those ridges, which always lie nearly parallel to the line of motion of the whole glacier, because this is the direction of its general fall or declivity. Now as those heaps or ridges slope off *thin* towards their sides, and are, at their highest points, often many feet in thickness; they act, with respect to the sun's rays, as *heaters* towards their edges to melt down the ice beneath more rapidly, on the same principle as the isolated stones before described, while nearer the centre, their thickness being so much greater, and the mass being of itself, at the temperature of the winter snows, acts as a non-conducting protector *or coating* to the ice on which it rests, preventing its melting so fast as the uncovered surface at large, while the immediate edges of the "Moraine" melt the ice under *them* even faster than the general uncovered surface.

The consequence of this obviously is, that each ridge of debris, as first deposited, Fig. 11, has a tendency to form for itself an elevated seat or ridge of ice whereon it rests, Figs. 12, &c., and accordingly some of these ridges of stones and gravel are found elevated on seats of ice five and twenty feet or more above the general surface of the glacier; but as it was before shown that the central portions of the glacier sink most rapidly, it is obvious that each of these icy pyramids, with its cap of débris, has a continual tendency to topple over and fall from either side towards the centre of the glacier, or at least to discharge its load of matter towards the centre, Figs. 13, 14, &c.; so that by the continuance of this process, every one of these mountain ridges is transferred parallel to itself from the place of its first formation to the centre of the glacier.

After the ridge of ice beneath the debris has risen to a certain height, water begins to collect, the superficial drainage of the ice being detained at the upper side of it, or that farthest from the centre of the glacier. This water, as it runs off gradually, undermines and cuts through the ridge of ice, until it is finally sapped, and falls to pieces, Figs. 14, 15, &c. after which the whole process, stage by stage, as above described, is again repeated. It will now be seen that during the progress of the changes just described, a lateral transfer of the whole mass of "Moraine," equal to the distance A, B, Figs. 11 to 15, has been effected.

Hence it happens that the greatest deposits of "Moraine" are found nearest the axis of the whole glacier, where they act as protectors to that portion of the ice, to prevent its too rapid melting, it being there exposed to the maximum liquifaction beneath, and but for these masses most exposed from above to the sun's rays; so that it is probable, were it not for this conservative action of the "Moraine" in the great economy of these mighty machines, the larger glaciers would soon be *melted through* along their centres, and thus the whole mechanism of their motion destroyed.

Besides this use of the "Moraine," by portions of it continually falling into the crevices, it forms various subglacial inequalities and obstructions, tending to the further subdivision of the ice in the various ways before described, while by the tremendous collision and friction of the blocks of ice, the substance of the included debris is abraded and ground small, and thus reduced to a more fit state to be discharged by the subglacial currents into the vallies below, where it is destined one day to form part of the alluvial soil. It results then, generally, from the combination of these forces, that when the winter has been most severe, the motion of the glaciers during the succeeding summer is most rapid, and *vice versa*, thus beautifully preserving the equipoise of temperature in the adjacent regions.

It would be impossible, within reasonable limits, to show this at length by a collation of meteorological tables, with observed periods of increase or decrease in the glaciers. The *decrease of a glacier* is only a relative term, and has occasioned some mistakes; it merely means that the rate of advance of the glacier into the valley being for a term less than usual, and its lower end being continually melted off and degraded in the warm valley, it appears less in magnitude for a time, until some fresh "start" makes up for the temporary deficiency. But it may be remarked, that during the summers of 1817 and 1818, (when the glaciers of Osterl and Weisshorn, as before described, fell, during these severe winters,) the descent of the glaciers was unusually great, and was not confined to Switzerland alone, but was also remarked in the Polar glaciers or icebergs proper, and ice-islands or floating islands of ice came as far south as the West India islands, one of unusual magnitude having reached the Bahama isles. As the bed of a glacier is in continual process of degradation, or *deepening* by the resistless passage of these vast masses of ice and rocks over it, so is its temperature by consequence continually on the increase, unless equilibrated by a general rise in the level of the country, in which it exists, and hence the rate of descent or the amount of waste of a glacier in a given time, must proportionally increase; and as the fall of all Alpine torrents is so rapid, it is improbable that the increased supply of water to them from this cause, will proportionally increase the amount of evaporation, and consequently of atmospheric precipitation within the Alpine limits. Hence the important geological conclusion is arrived at: that *the tendency of all glaciers is to eat themselves out, and in the course of ages to disappear*, and be succeeded by others at a greater altitude in the mountain chain, and of a less magnitude, consequent upon the local amelioration of climate produced by the removal of the ancient ones.

Whether this conclusion is just and capable of accounting for the historic records of amelioration of Alpine climate, and for the traces discoverable of ancient glaciers must be determined by future lengthened and cautious observation. Although the genius of Arago has shown that no universal change of climate of appreciable extent can have effected our earth within the historic period, yet it is absolutely certain, that great local changes of climate have taken place within that era, and some in comparatively recent times, which have been produced mainly by the motion of the very body we now treat of, namely, masses of ice.

Agassis, in a late number of the Edinburgh Philosophical Journal, has described what he considers, with apparent reason, as the traces of ancient glaciers on the flanks of Jura, occupying a district stretching twenty leagues east and west of Neufchâtel. The rocks here on being stripped of their alluvial covering are found literally *polished*, and covered with furrows in a direction oblique to the mountain range, as if cut by the scratch of a diamond. It is also remarkable that great lines of gravel beds and boulders, as if the deposits of ancient "Moraines" are found arranged in this same locality.

While Professor Agassis ascribes the production of these furrows and scratches to the transport of ice, he is at a loss to find the source of the latter, and admits the difficulty of supposing masses of ice borne from the High Alps, across the lake of Geneva, at an altitude of some hundreds of feet above its present surface. The conclusion we have here arrived at, however, justifies us in considering it not impossible (to say the very least) that time was, when the sides of Jura were ploughed up by glaciers projecting themselves into the lake of Geneva itself, which have in the course of ages given place to those now in existence in the higher Alps, and which shall, in their turn, if the duration of the present economy of our earth permit, disappear, and be succeeded by others still more elevated.

Two observations are proper to be added to this view.—First, that the assigned operations are *independent* of any relation between the level of the belt of glaciers and the line of perpetual snows; and, secondly, that the rate of progression of the process in question must be a continually decreasing one, both of which are sufficiently obvious. It is also plain, that the general rise or depression of level of a glacier country, with respect to that of the sea, or the fall upon a glacier of a mountain-mass, such as a landslip, will produce corresponding increase, or diminution, or total destruction of glaciers so affected, according to circumstances.

There is one minute, but very interesting circumstance connected with the disintegration of glacier ice, as to the nature of which I would offer a conjecture, namely, while the ice forming the interior of the mass is upon the whole sound, that which forms its surface is for some inches in depth generally found fractured; it consists of fragments about the size of white sugar when broken for use, whose lines of separation are curves closely fitting together, so that the general aspect, as to the *form* of the mass, is very similar to that of the mineral called "coccolite," or to starch when dried in lumps. Now, as Sir David Brewster found that ice, although massive, showed by the aid of polarized light, a crystalline structure, and from its having one axis of double refraction, predicted that it belonged to the pyramidal or rhomboidal systems, it is possible, though improbable, that its crystals, whose form is yet undetermined *experimentally*, may expand and contract unequally by change of temperature. Now, although the temperature of the surface ice of a glacier can never *rise* above 32° fahr., yet it may *fall* far below it, and hence such forces be brought into play by unequal contraction, as may cause separation of its parts; and this is countenanced by the curved planes of separation, indicating that the disrupting forces are *within* the mass. This, however, I only throw out as a conjecture, worth verification or contradiction by those who happen to be placed in a suitable climate, and who possess the other means of doing so.

The connection and relations of these forces we have been considering with the atmosphere, with winds, dews, clouds,

&c., and their united effects in modifying the condition of glaciers, and the reaction of these upon the climate where they exist, as belonging to meteorology, would form matter for a separate investigation, as does also the question, why glaciers are found in some mountain chains and not in others, though having nearly the same climate. One remark, however, I would make on this head, with respect to the prevailing winds produced by a glacier over its own surface. Count Rumford, and indeed almost every author on the subject, state, that *the warm air from the vallies is carried over* the surface of the ice; the very reverse, however, is the fact, for as the column of air, at the side of the valley opposite to a glacier, which does not repose upon ice, is warmer than that which rests upon the glacier itself, it is obvious that by this disturbance of equilibrium a motion of descent will be produced in the colder or denser column; and hence, as is found to be the fact, each glacier will discharge a current of cold air into the valley below it.

This great general direction of wind, however, is modified by season and locality, and also subject to regular diurnal changes, analogous to, and produced by similar causes, with the sea and land breezes which prevail in Tropical islands.

So far as I have endeavoured to trace, as accurately as I was enabled, the nature of the motions of glaciers and their results, assured of their importance to the geologist, and that the approximation of geology to exactness and truth, will depend much more upon the extent to which physics can be brought to bear upon its observed phœnomena, than upon the mere questions of locality and epoch, which so much engage ts cultivators.

Of the vast field of operation of glacier's forces, some idea may be formed by stating, that in Switzerland alone, there are above four hundred known glaciers, most of them from eight to eighteen miles in length, and from one to four miles wide, with an average depth of from one hundred to six hundred feet; so that within the small area of Switzerland, we find approximately, that about thirty-one millions and a half cubic fathoms of ice are translated annually, by an average distance of twenty feet horizontally, and bearing upon them an unknown weight of stony detritus, without considering at all their vertical descent.

In conclusion, I trust, I have been enabled to show that even a glacier, the very emblem of havoc and desolation, is yet subservient to fixed and designed laws; we have the very highest authority for believing that time was, when our earth, pronounced by its beneficent author as "very good," *needed not* that system of counteracting and mutually *equilibrating forces*, in which we now see "creation groaneth and travaileth together;" and we are given to hope, that time shall come, when this economy, wonderful and grand though it be, shall give place to one more perfect and harmonious.

It therefore would seem, but a half-formed philosophy of those who see in the tremendous, but still regulated results of the volcano, the earthquake, the tempest, or the glacier, evidences of nothing but of a great and provident First Cause, forgetful how these also indicate that creation was once cursed for man's sake. Yet viewed aright, it is neither an unworthy nor a useless theme to discover how these elements of discord and destruction are curbed for a time with pre-ordained laws by Him "who hath weighed the mountains in a balance, and measured the waters in the hollow of his hand."

ON THE DILUVIAL OR NORTHERN DRIFT OF THE EASTERN AND WESTERN SIDES OF THE CAMBRIAN CHAIN, AND ON ITS CONNEXION WITH A SIMILAR DEPOSIT ON THE EASTERN SIDE OF IRELAND, AT BRAY, HOWTH, AND GLENISMAULE.

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PART II.—THE WESTERN SIDE OF THE CAMBRIAN CHAIN.

Having traced the northern drift from the mountains of Cumberland, down the eastern side of the Welch range into Worcestershire, and having stated some of the objections to that hypothesis, under which it is supposed to have accumulated gradually at the bottom of the sea, the boulders being transported on ice, let us now return to Lancashire and Cheshire, and trace it down the western side of the same range, where we shall find conclusive evidence of its having passed over pre-existing land. Besides, the section already described on the left bank of the Mersey, near Runcorn, others occur on the right bank of that river, near Garston. The northern drift also covers the whole district between the estuaries of the Mersey and the Dee. Fragments of existing species of shells may be seen in the low bank of red loam at Woodside Ferry, opposite Liverpool, affording a striking contrast to the estuary deposit of black silt, now forming by the Mersey. Shells always in fragments and accompanied by northern detritus, occur at intervals on the right bank of the Dee, in sections of the undulating ground, skirting the marshes in which the estuary of that river terminates. I have traced this deposit from Shotwick, five miles below Chester, to near Parkgate. The fragments of shells are small and by no means abundant; but pebbles and boulders of granitic, porphyritic, and transition rocks, occur in considerable quantities.

The upper part of the estuary of the Dee, near Shotwick, consists of marshes reclaimed by embankment. Near Burton Head are marshes occasionally overflowed by the tide, and a little below that point all traces of verdure disappear, and banks of mud and sand commence, which are covered every tide, except that a sand bank near the Welch side and opposite the town of Flint, is dry during high water of neap tides.

These marshes and sand banks forcibly remind us of the estuary deposit which Mr. Smith finds on the banks of the Clyde, elevated 40 feet above the influence of the tide. The marshes are composed of finely laminated silt—the lamination persistent over great spaces—and the shells of *cardium edule* and *Tellina solidula*, together with bones of sea-fowl and of fishes, claws of crabs, fragments of sea weeds, and branches of trees strew the surface on which the tide still continues to throw down silt. It does not, therefore, necessarily follow, that a deposit of this kind must have been formed in deep water, or even that it need have been constantly covered.

In crossing the sands at low water from Parkgate to Flint, a similar mixture of marine and terrestrial remains, is observable, immense quantities of bivalves, chiefly of the two species above-named, are imbedded in sediment with the two valves for the most part united. *Buccinum undatum* and *Mytilus edulis* are more rare. Branches of trees, oak-leaves, the heads of reeds, and sedge plants strew the surface of the sand, while occasionally a dead fish may be observed in the process of decomposition, and on turning it up it will be found that its general form, together with that of the scales, bony protuberances and fins, is as delicately impressed upon the sediment as in the fossil ichthyolites. I again repeat, that I have never observed these indications of tranquil deposit in any portion of the northern drift. The northern drift is likewise spread over the whole of Cheshire. I have seen broken shells and granitic detritus in most of the cuttings on the Grand Junction Railway, between Liverpool and Northwich. They have been observed by Sir Philip Egerton and Dr. Buckland, in nearly twenty localities in that county, besides the section at the Willington, where Sir Philip Egerton describes them as covering a *raised beach;* a grinder of an elephant is now in his possession, found in some railway cutting near his residence in the autumn of 1836. They may be seen in the brick-fields near Chester, and thence at intervals to the neighbourhood of Flint, and from Flint they may be traced to Conway. I have only observed the deposit near the coast, and have not yet followed its range inland. It may be as well to enumerate a few points where sections may be seen in Flintshire and Denbighshire.

Granitic detritus and fragments of shells occur in a bed of clay, dug for brick-making near Messrs. Walker's lead works, at Bagillt, scarcely 20 feet above the estuary of the Dee. They also occur in loam sand and gravel, at the height of about 200 feet on the new road from Hollywell to Bagillt, about a quarter of a mile from Hollywell. They are also found in clay in a brickfield, close to the entrance into St. Asaph from Hollywell, and in a cliff of reddish loam, about 40 feet high, on the right bank of the river below the bridge at St. Asaph.

The vale of Clwyd is loaded with this deposit of considerable thickness, and lodged at various heights, being covered in the bottom of the valley by the alluvial deposits of the Clwyd and Elwy. In this neighbourhood two remarkable mixtures of marine and terrestrial remains occur, one of which establishes, beyond the possibility of doubt, the fact, that here the northern drift has passed over dry land at a point now nearly 200 feet above the sea; and if this can be proved to have taken place here, why should it not also have happened in situations of the same, or even less elevation in the valley of the Severn, near Shrewsbury? Why, in short, may not the passage of diluvial currents over the land be admitted into the catalogue of geological agencies, as well as the transport of boulders on ice across the Baltic, or the gradual elevation of the Scandinavian peninsula? The first of these mixtures of terrestrial and marine remains which I shall notice, occurs in Talargoch lead mine; and if the gravel workings of that mine had been watched by geologists during their progress, much valuable information might have been collected, bearing on this department of geology; but at present, from the suspension of this part of the mine, the mode of association of the terrestrial and marine remains, is involved in much obscurity.

Dr. Buckland, in his Reliquiæ Diluvianæ, after noticing the occurrence of remains of the elephant in the vale of Clwyd, and near Dyserth, in diluvial gravel, containing rolled pieces of lead analagous to the stream tin works of Cornwall, gives the following sections at the Gronant and Talargoch Mines, on the authority of C. Stokes, Esq., and Robert Dawson, Esq.:—

GRONANT MINE.

1. Vegetable Mould, 2 feet.
2. Clay mixed with some sand and rolled stones, 26 yards.
3. Gravel beds, containing rolled pieces of lead of various sizes, 8 yards.

He then adds, "In another mine called Talargoch, the remains of ox and stag are found at present (1824); and in 1815, a pair of stag's horns were discovered 60 yards below the surface, and are now in the possession of the Earl of Plymouth, at Tardebig. The section at this mine is:—

1. Vegetable Mould, 2 feet.
2. Clay, 26 yards.
3. Sand and gravel containing pebbles of copper as well as lead, 68 yards. Horns, teeth and bones are found in it at from 40 to 70 yards from the surface, and also at the bottom of the gravel, in immediate contact with the subjacent limestone. Another shaft, dug one mile south of St. Asaph, between the Elwy and the Clwyd, presented irregular alternations of clay and gravel to the depth of 88 feet.

These notices of organic remains in the detrital deposits of that neighbourhood, are confined to the occurrence of terrestrial exuviæ, but Thomas Harrison, Esq., of Saethaelwyd, the proprietor of the mine, lately presented to the Caernarvon Museum, through Richard Garnons, Esq. of Colomendy, two bones which were stated to have been found in Talargoch Mine, several years before in a bed of gravel at 63 yards from the surface, accompanied by marine shells.

Dr. Buckland, to whose inspection I submitted these bones, pronounced them to be the astragalus of a large, and the humerus of a small deer; but he was not in possession of any further information respecting Talargoch Mine, than that contained in the extract above quoted from his Reliquiæ Diluvianæ.

On a visit to this mine, in company with Dr. Scouler, since I had last the honour of addressing this Society, I obtained the following information partly from the workmen, and partly from my own observation:—The detrital deposit (*c.*) section IV., containing pebbles and boulders of lead, is situated on the north side of a hill of carboniferous limestone, with a northern dip, which forms a promontory, bounding the estuary of the united streams of the Elwy and the Clwyd on their right bank, and it is distant about two miles from the seaward extremity of the delta of those rivers which, has been converted into dry land, partly by natural processes, partly by embankment. The height of the surface of the mine above the sea cannot be less *from the depths* above given than 300 feet. The sloping face of rock (*a*) on which the detrital deposit (*c*) rests, is the heading side of a lead vein (*b*), in which the workings are now carried on, those in the gravel having been discontinued for twelve or fourteen years. The depth and order of arrangement of the beds of clay, gravel, &c., as described by the miners who had worked in them, agreed in general terms with those given in Reliquiæ Diluvianæ, but were less precise. They spoke of horns of deer, bones, shells and timber, as having been found in the gravel; and Mr. Jones, the superintendent of the mine, gave me a specimen of *purpura lapillus*, two of which had been lately found in sinking a shaft at the eastern end of the works. These appeared to have been the only specimens of whole shells observed, but the miners described a bed of gravel near the western end, as having been met with many years ago, abounding with "cockle-shells," all in fragments.

In working the detrital lead, shafts were sunk through the clay, and galleries, supported by timber, were driven along the beds containing the lead, and masses are said to have been found so large as to have yielded 80 tons of ore.

By the side of the road, near the western end of the mine, I found fragments of shells and granite pebbles in a bed of reddish clay or loam. In the old rubbish heaps which were pointed out to me by the superintendent, I also detected similar fragments of shells, and a few limestone pebbles, which had been rounded by attrition and perforated by boring molluscs, (1) but by far the larger portion of the detritus, consisted of fragments of limestone either angular (2) or only slightly water-worn (3). I could not find any fragments of Northern rocks in these old rubbish heaps, but I obtained some from a small recent excavation near the western end, where an opportunity was likewise afforded of seeing the surface of the limestone in contact with the loam containing fragments of shells. The rock there afforded no traces of molluscous perforations, and the workmen said that they had never observed any. In the present state of the works then, no very decisive evidence can be obtained, whether the marine remains were deposited on the shore of the neighbouring sea, and subsequently elevated, or whether they were thrown up by the sea on the land. The drilled calcareous pebbles may be regarded as a further proof, besides the two specimens found near Dublin, that boring molluscs existed in those seas at the time of the dispersion of the northern drift, and they therefore give value to the negative evidence of the absence of perforations on the limestone, and limestone fragments of other localities. Perhaps some geologists may consider them as occurring in sufficient abundance to bring the deposit under some of the conditions I have laid down, as necessary to constitute a raised beach. In the absence of information as to the mode of their occurrence, it can only be replied, that the slight degree of attrition which the mass of the detritus appears to have undergone, is at variance with this supposition, as is the extreme rarity of whole shells, none having been observed, except two specimens of that strong shell (4) *purpura lapillus;* the bones likewise in the Caernarvon Museum, which were found in company with marine shells, have undergone little or no attrition.

It is not necessary to suppose the pebbles of lead to have been drifted from any distance, from the Halkin Hills, for instance, as suggested in Reliquiæ Diluvianæ, since it is evident that the hill contains alode of lead, from the destruction of the upper part of which the detrital lead was in all probability derived. The large masses stated to have occurred in the gravel favour this view, and may, by some, be considered proofs of movements of elevation, which had shattered and broken the limestone and the vein contained in it.

On the whole, therefore, the evidence appears to be of such a nature as to leave it doubtful, whether there may not here have been some marine deposit of slow accumulation under the northern drift, instances of which have been recorded by others, though none have yet fallen under my own observation. In the present state of the detrital deposit of Talargoch, we must interpret its phenomena by those of the neighbourhood; and Cefn Cave, about six miles further inland, affords decisive proofs of the passage of the northern drift over the surface of pre-existing land, though under circumstances which seem to indicate a difference of about 100 feet between the ancient and present levels of the adjoining river Elwy.

A description of this cavern, illustrated by numerous drawings of the caves and bones, a ground plan and a manuscript map of the district was communicated by the Rev. E. Stanley, now Bishop of Norwich, in 1832, to the Geological Society of London, and the following abstract of the paper is taken from the proceedings of that Society, vol. 1, p. 402. After describing the physical features and present drainage of the district, the author shews, that if the pass between the Cefn and Galltfaen Cliffs were filled up, the river Elwy would be converted into an extensive lake, occupying the vale of Cyffredan, on the eastern side of which the caves are situated. The lowest cave raised but a few feet above the level of the river, forms a natural archway, penetrating through the limestone cliff, and affording a passage for a road. In its lateral ramifications human bones, the horns of a deer, and works of art have been found, but no remains of extinct animals. About 100 feet above the level of the valley, two other caves are situated in the face of the precipitous limestone cliff, but only one of them has been much examined, and it is to this cave in particular that the memoir refers. When it was first discovered, the interior, from the level of the entrance to a short distance from the roof, was occupied by a calcareous loam, in which a few angular masses of limestone, part of the humerus of a rhinoceros, teeth of a hyæna, and numerous fragments of bones were found. Beneath this accumulation, and beneath what had been considered the floor of the cave, his lordship ascertained the existence of another deposit of similar loam, besides fragments of bones, and small portions of wood and rounded pebbles.

The cave was found to have several branches, one of which was traced in a southern direction till it terminated in the face of the escarpment, opposite the Galltfaen Cliff; but the real extent of the other branches has never been determined. The author after these details enters into an inquiry respecting the former physical structure of the district, and the mode in which the contents of the cave were deposited in the position in which they were found. He conceives that the Vale of Cyffredan was formerly occupied by a lake, and that the surface of the vale was once nearly on a level with the entrance of the cave; and he explains the position of the loam, and associated pebbles and bones, by supposing, that a sudden flood rushing through the valley, carried into the cave the pebbles and fragments of wood and loam, found in its lower part—that after the inundation, no similar catastrophe occurred for an unknown period, during which the caves again became the resort of wild animals; that at the close of that period, another and more powerful flood occurred, rising above the level of the cave, and depositing within it the loam which occupied the greater part of its cavity; and that this flood overcoming every obstacle, excavated the valley to its present depth.

In the autumn of 1836, Cefn Cave was visited by Dr. Buckland, who shortly afterwards expressed to me an opinion, that fragments of shells might be found there, adding, that he was too much hurried, and accompanied by too large a party, to search for them; but, that the next morning, at the moment of departure, he found them in gravel, brought up from a well, then digging near Mr. Lloyd's door, at an elevation not much differing from that of the cave. This conjecture I have been so fortunate as to be able to verify, having discovered within the cave, in the upper part of the deposit of marl and angular pieces of limestone, two seams of sand, separated by a few inches of finely laminated marl, and in one of them I have found fragments of marine shells, similar to those which have been described as occurring in the detrital matter spread over the whole surface of the district.

The situation of the marine deposit clearly proves, that by whatever means the loam and pebbles were deposited, the last operation was the introduction of the northern drift, probably through the roof, for it will be shown presently, that one branch of the cavern communicates with the surface, and is now the resort of some wild animal, probably a badger.

It must be premised, that the marl with which the cave is filled is extracted for manure, and thus a considerable length of the cavern has been cleared down to the level of the entrance; but the deposit of bones in marl, with smooth waterworn pebbles, described by the Bishop of Norwich as lying below this level, has only been penetrated by holes sunk in one or two places. There appeared to be more than one layer of bones and stalagmite below the level of the entrance, but I paid little attention to that part of the subject, being chiefly occupied with the search for marine remains.—These occur in the forebreast of the workings of the main branch of the cave, of which section V. is a tranverse section.

a. The lower deposit of bones with waterworn pebbles, chiefly of greywacke below *b.* :

b. The level of the entrance of the cave, down to which the marl is extracted.

c. The deposit of marl, sometimes finely laminated (5), containing angular pieces of limestones and bones.

d. The deposit of sand (6), containing marine remains divided by a few inches of marl; the total thickness of the sand and marl being under two feet. It is covered by a very thin crust of stalagmite, between which and the roof of the cavern, there is at this point, the space of only a few inches. I found no shells in the upper seam of sand; but as it is of the same character as the lower, it is probable that they may hereafter be found. The fragments are small, and by no means abundant: on being dried, some of them crumble to powder, but others are more durable; among them are some which may be clearly recognized as belonging to the genus cardium (7), one specimen which I sent to Dr. Buckland retained its colour, as is frequently the case in the northern drift. The bones when dry, adhere to the tongue. The cave is very free from moisture, and stalagmite by no means abundant. A lateral branch out of which the marl had been worked for a considerable distance was a cavity, so lofty, that I supposed it to have been a fissure communicating with the surface, the upper part of which was closed by mud, but the guide assured us that there was solid rock above our heads. In the fore-breast of the works we found the roof lower, and a vacant space of about 10 feet between it and the surface of the loam, which rose 8 or 10 feet above the level of the entrance. On climbing to the surface of this loam, where we were told nobody had ever been before, we found, that in the length of about ten feet; the roof approached so close to the loamy deposit, as to leave an aperture of not more than 8 inches in diameter between them. The surface of the loam was covered by a crust of stalagmite on which was a layer, a few inches thick, of black vegetable mould, containing the stalks of fern. A current of air sufficiently strong to extinguish the candle blew through it; and, as a further proof, that it communicated with the surface, the black soil was beaten hard by an animal passing over it—the beaten surface contained some recent scratches from his claws, and hair appearing to be that of a badger (8), was trodden into the soil; a point of limestone also which projected into the aperture (9), was polished by his passing and repassing.

The upper part of the River Elwy flows through a greywacke country, and it is only a little above the cave that it enters the limestone district. Its pebbles are a mixture of greywacke and limestone—chiefly the former, agreeing in that respect with the water-worn pebbles of the lower part of the cavern; and the turbid waters of the river, which at the time of our visit was swollen by the heavy rain of the preceding day, indicated the source from which the marl of this part of the deposit was derived. The archway in the rock, a little above the river, appears to have been once blocked up with a similar deposit of loam and pebbles, some of which still adheres to the sides.

To the river, then, we must look for the deposit of the lower part of the cavern, and the difference between its present level, and the mouth of the cave may be explained in various ways:—

1st. As suggested by the Bishop of Norwich, the pass between the Cefn and Galltfaen Cliffs being closed, the Vale of Cyffredan may have been a lake.

2nd. The river flowing nearly at its present level, a land-slip may have occasioned a temporary obstruction, which caused it to throw pebbles and silt into the mouth of the cavern.

3rd. The river flowing formerly nearly on a level with the cave, may have slowly cut its way down to its present bed.

4th. The erosive process, combined with some movement of elevation, may have effected the change in a comparatively short time.

5th. This may, in part, have been accomplished by the retiring waters of that inundation which deposited the marine remains in the upper part of the cave.

An attentive study of the phenomena of the cave and its neighbourhood, may probably enable us to decide to which hypothesis the preference ought to be given; but this conclusion is independent of them all, viz., that at the time of the distribution of the northern drift, the site of the Cefn Cave was dry land, and that sufficient dry land existed around it to support the larger mammalia.

Two limestone cliffs near Gwyrch Castle, about two miles from Abergele, on the Conway road, afford many cavities, containing mud and pebbles. In the face of the cliff is the mouth of a cavern fronting the sea—about 300 feet above its level, and distant from it about a quarter of a mile. At a few feet within the entrance, an open fissure communicates with the surface, and under it is a great heap of angular fragments of limestone and loam. At about twenty yards from the entrance the cave becomes dark and wet, and much obstructed with fragments of rock; and being unprovided with a light, I followed it no further. A small branch is almost wholly blocked up with the loam at a few feet from its commencement, and appears to be the resort of foxes.

Neither on the face of the cliff, nor within these caverns, could I discover any traces of lithodomous perforations. Perhaps bones, or shells, and northern drift might be found, by excavating beneath the masses of loam and angular fragments. The adjoining extensive quarries have laid open several cavities completely filled with loam and gravel, and having the appearance of insulated patches of detrital matter enveloped in solid rock. They, doubtless, communicate by swallow holes and fissures with the surface. The pebbles embedded in the loam are flat, smoothly water-worn, and consist almost entirely of two kinds of friable micaceous sandstone, the one dark red (10), the other yellowish green (11); similar pebbles occur, mixed with others, in the northern drift of the vicinity. I could see no traces of bones or shells, and could obtain from the workmen no account of any having been met with, except a human skull in the surface soil.

Several masses of loam and gravel which have evidently filled cavities and fissures, remain standing in another part of the quarry, the limestone having been worked away from them. These deposits, even in masses closely adjoining one another, are of a more variable character than the last. The prevailing ingredients are smooth flat pebbles, of the two kinds just mentioned, (10 and 11). In some, these are mixed with fragments of greywacke slate, also water-worn—one has been chiefly filled with fragments of limestone, only partially abraded, as they generally occur in the diluvial deposits; and here I found two specimens of Syenite (12); another has smooth spheroidal pebbles of limestone (13) at the bottom, and over them, a mixture of the red and greenish sandstone (10 and 11), and greywacke and limestone. At the west end of the quarry, a wall of detrital matter, from which the rock has been quarried away, and which has evidently accumulated in an open fissure, gives the following section (sec. vi. fig. 1, 2):

a. Loam with a few pebbles, 6 feet.

b. Gravel, consisting chiefly of red and greenish sandstone, (10 and 11), 5 feet.

c. Loam, mixed with similar gravel, 5 feet.

d. Reddish clay, 4 to 6 inches thick, having a layer of calcareous tufa, (14) above and below it, and containing numerous bones of moles and mice (15), that have not lost their gelatine, mixed with shells of helix.

In some parts there is a third layer of tufa dividing the osseous clay into two. This osseous deposit, the upper tufa, of which is covered with quarry refuse, may be traced for 15 or 20 feet; beyond which, the fall of the ground renders it inaccessible.

From the vicinity of Abergele to that of the little Ormes Head the coast is bounded by diluvial cliffs, the greatest height of which may be about 100 feet; but they gradually decline in height, till they sink into the low level tract between Abergele and Rhyddlan. From the greater part of this shore the sea appears to be at present receding, and the cliffs have become mere grassy slopes; but near Llandulas, for about a mile, they are exposed to the wasting action of the sea, and afford good sections. The lower part of these cliffs consists of a very tough bluish, or brownish clay, containing fragments of shells with embedded pebbles of northern granitic, and transition rocks and limestone; but the last is by no means abundant, although it is the rock immediately subjacent. This deposit passes upwards into a reddish loam and gravel. The limestone pebbles have undergone very little attrition, and are not perforated by lithodomous molluscs. Having searched in vain for these in other places where calcareous fragments occur in the detrital deposits, I have cited the fact, as a proof of the shortness of the time, during which, they were exposed to the action of the sea. To this argument it has been objected, that the absence of these perforations merely proves that lithodomous molluscs were not established in these seas during that period. They occur in the Tertiary deposits of the eocene epoch. We have them in the crag, and they are found in the newer pliocene strata—and yet they are wanting in the northern drift, and not only are they wanting, but balani and serpulæ also, which I have before observed, are so numerous on the non-calcareous, as well as calcareous rocks and pebbles of existing littoral deposits throughout the district we have been examining. Fertile as geology is in wonders, the existence of these three genera during the tertiary era, from its commencement to its close—their extinction during the epoch of the northern drift, and their re-appearance in the present seas, would certainly be one of its greatest marvels. At Glenismaule, out of many millions of limestone pebbles, not drilled, Dr. Scouler found one with decided perforations on it; and I obtained another from the same place, in which the marks appeared to have been nearly obliterated by attrition. I had expected that the detrital deposits of Flintshire and Denbighshire, where limestone is the prevailing rock, would have furnished sufficient drilled pebbles to have set this question at rest; but the only point at which they have been met with, is in the old rubbish heaps of Talargoch mine. The paucity of fragments of the subjacent limestone rocks in the cliffs at Llandulas, is in accordance with a fact I have observed elsewhere, viz., that on the sides of hills exposed to the sea on the north, fragments derived from rocks lying at a little distance to the north, are more abundant than those of the subjacent rock. The same remark has been made by Dr. Scouler respecting the deposits of Howth. In this fact, we have another violation of analogy, between existing littoral deposits and the northern drift, the raised beaches of some authors. Had these masses accumulated gradually beneath a sea, which for a long time washed the base of the hills, at the feet of which they are found, the greater part of the detritus would have been derived from the rocks on which it rests.

It has been already stated, that the greatest height of the cliffs of northern drift, near Llandulas, is about 100 feet; but about a quarter of a mile further inland, in a cutting on the new road, at the height of about 200 feet, a bed of reddish clay occurs, containing fragments of shells, and resting on a bed of sand, such as would have been produced by the abrasion of the new red sand-stone. The streamlet which crosses the road at the village of Colwen, has excavated its bed through banks of local detritus, in some places, nearly 40 feet deep. The fragments of the lower part of the mass are black greywacke slate, which have undergone but slight attrition, having a few smooth pebbles of the sandstone (10 and 11), so often mentioned mixed with them. The whole are embedded in clay, generally of a bluish colour, but in one part reddish clay is seen below this. Fragments of marine shells occur very sparingly in both parts of the argillaceous mass.—It passes upwards into loam and gravel, in which the fragments have undergone still less attrition, and in which no traces of shells could be detected.

It may be stated as a general fact, that the rivers which descend from the mountains of the slate region of North Wales, have cut their way in the lower part of their course through thick masses of detritus, derived from the rocks of the districts through which they flow, the proportion of pebbles which have been drifted in a contrary direction being so insignificant, that the detritus might be called local. Besides the case just now mentioned, instances occur in the river at Aber, the Ogwen and the Cegin at Bangor, and in a part of the Seiont above Caernarvon. The banks of the stream at Colwen afford the only instance in which I have yet detected fragments of shells, under such circumstances.

Between the Orme's Head and Bangor, traces of the northern drift occur on both sides of Penman Mawr; but we have few good sections till we reach the banks of the Ogwen.

It will now, perhaps, be better to describe the northern drift of Anglesey, before we proceed further with that of Caernarvonshire.

In professor Henslow's paper, on the geology of that island, published in the transactions of the Cambridge Philosophical Society, the following passage occurs:—

Deposits of diluvial matter are scattered over each of the chloritic districts, which bound Anglesey to the west. They occur in the form of very obtuse conical hills, the diameter of whose bases varies from about a quarter to half a mile, and the surface consequently presents a succession of gentle undulations clothed by culture, the subjacent rock being exposed only in hollows between them. The internal structure of these hills is exhibited in several places along the coast to the south of Llanfachlan, and also between Monachdu and Wilfa. They consist of fine grained sandy materials, deposited in layers; and in several instances it happens, that the coarser ingredients form the uppermost portion. The rolled pebbles are not numerous; and there are a few large blocks of schist, greenstone and limestone dispersed through them. From Penmon to Beaumaris there is a low cliff of diluvium, through which are dispersed numerous large blocks of limestone and grit, derived from the coal measures. This terminates immediately to the south of Beaumaris, in a mass about 60 feet thick. The character of this diluvium does not resemble that which is found to the west of the island, where it bespeaks a succession of deposits, but forms a rude mass, in which the materials appear to have been brought together by a single effort. The smallest and most rolled, consist of various granites, traps, and the older stratified rocks. Some of the blocks of limestone, and of the more recent strata, are of very large dimensions, especially as we approach the mountain limestone of Penmon.

The cliff thus described was one of the first places in which I discovered fragments of shells. I have also found them in other deposits covering greywacke, near its junction with the chlorite schist, a little east of Llaneilian mountain; also resting on limestone, near the western boundary of Red Wharf Bay. At this latter spot an opportunity was afforded of seeing the limestone within the tidal limits, and also of seeing its surface only a few feet above high water mark, beneath the diluvium, which had been removed in quarrying the stone. Up to the high water mark, the rock was drilled by lithodomi: beneath the diluvium only a few feet above that level, it exhibited no traces of the action of these molluscs, but its surface was polished and scratched.

I have never seen the sections south of Wilfa and Monachdu, but from professor Henslow's description, they appear to be similar to an extensive range of cliffs in Caernarvonshire, near Porthdynlleyn, which will be described hereafter, and in which I shall shew that beds of finely laminated sand pass horizontally into a tumultuous mass of mixed materials, which has every appearance of having been brought together like that at Beaumaris, by a single effort.

We will now return to Caernarvonshire, and the banks of Ogwen. The thick deposit of detrital matter through which that river has excavated a channel commences at about two miles and a half from Bangor, near Lon Issa Tollgate, on the parliamentary road; and descending the stream from that point, the following sections are observable; the order of the different beds enumerated, commencing from the surface. Near Lon Issa gate:—

		Feet.
1.	Cultivated soil, 6 inches - - - -	0,6
2.	Coarse gravel and veins of sand, confusedly mixed	40
3.	Loam, with boulders down to the level of the river	77
		117,6

A little lower down the stream the following section occurs on the right bank :—

	Feet.
1. Cultivated soil, loam	2
2. Gravelly loam, without many large boulders	20
3. Loam, with large boulders	46
	68

Another section on the left bank of the river gives :—

1. Loose coarse gravel, rounded	15
2. Loam, with boulders,	25
3. Hard gravel, cemented into a conglomerate by oxide of iron and manganese	22
	62

Another section gives :—

Loam, with boulders	25
Hard gravel	20
Loam	4½
Hard gravel	4½
Loam	4½
Hard gravel	4½
	63

The last section met with, in descending the stream, is a little above Landegai Bridge, and consists of an unstratified mass about 30 feet thick, composed of large pebbles and boulders, cemented together by gravelly loam. The largest boulders, some of them three feet in diameter, occur in the upper part of the mass. The fragments contained in the gravel and loam of the above sections, are, for the most part, derived from the rocks through which the upper part of the river flows, and they have undergone, in general, but little attrition : a few fragments of carboniferous limestone and pebbles, of northern granite, have been found among them, but they are extremely rare. No fragments of shells have been found in any of these sections.

The river flows in a trough much more wide and straight than the present stream, excavated in the mass of detritus above described, and it is only where the salient angles of the river touch the deep banks of this trough that the sections we have given occur—the banks in other places being covered with vegetation. Within this trough are two terraces, each about eight feet high, occasioned by the river having flowed at higher levels than at present. Higher up the stream than Lon Issa, there are no great accumulations of detritus on the banks of the river, which flows either between bare rocks or through alluvial flats, but near the village of Bethesda, about a mile from the right bank of the river, and about 100 feet above it, occurs that deposit of loam and boulders, enveloping detached masses of angular fragments of the subjacent slate rock, which has been represented in Section II. At about eight miles from Bangor, four from the river, and at an elevation approaching to 1,300 feet above the sea, there is a deep deposit in a lateral valley, in which I have seen pebbles of granite and of carboniferous limestone brought up from a shaft sunk to the depth of sixty feet. The workmen reported that they had found shells in veins of sand near the bottom of the shaft. This was before the discovery of shells on Moel Tryfan, and the specimens exhibited to me had not lost their translucency, a circumstance which it now appears is by no means uncommon in the northern drift, but it led me then to disbelieve the statement.

On the banks of the Menai we have no diluvial accumulations worthy of notice, except between Moel y don Ferry and Caernarvon, where several sections of the undulating hills on each side of the straits shew unstratified masses of gravel and loam, varying from 10 to 40 feet in depth. Fragments of Anglesey rocks are common on both shores, but the detritus of Caernarvonshire rocks is rare on the Anglesey side. The violet roofing slate is a Caernarvonshire rock easily recognised, and ranging parallel with the straits on their eastern side at a distance of about seven miles. The only spot on the western shore where fragments of this rock occur in any considerable quantity is in a mound of gravel about forty feet thick, opposite the mouth of the Seiont, which rises in the centre of the roofing slate district of Llanberris.

In none of these sections on the shores of the Menai have I been able to detect any fragments of shells, or drilled calcareous fragment, though pebbles and boulders of carboniferous limestone abound in them, and though those fragments are literally devoured by *Lymnorea perforans*, (16) as soon as they are detached from the diluvial accumulations and come within the tidal limits. This fact has been announced so often that it will be repeated no more, but may be understood whenever calcareous fragments are mentioned as occurring in the northern drift. When these accumulations rest on the red marl of the Poikilitic series, the surface of the marl beneath is worn into hollows and gullies.

Near the opening of the straits, into Caernarvon bay, there is a small estuary called the Voryd, running south for several miles, separated from the sea by a ridge of sand hills, and terminating in a marsh called Morfa Dinas, which is protected from the sea by a bed of shingle, and was overflowed by the Voryd, until secured by embankment. This estuary, the marshes, and some low undulating hills of diluvium occupy the whole space between the coast and the Clynog road, as far as the gate of Glynllifon park; thence a low diluvial ridge rising from ten to twenty feet above the marsh, extends down to the shore and divides Morfa Dinas from another marsh further to the south. This ridge terminates in two higher hills, one of which crowned with an ancient entrenchment is called Dinas Dinlle. Its height above the sea, exclusive of the entrenchments, is about 70 feet. Its base covers an area of 300 yards by 200. Towards the sea it presents a precipitous face in which its internal structure is displayed. This consists of above twenty irregular alternations of gravel, loam, clay, and sand, the strata inclined at an angle of about 45°—as shewn in section IX. The nature of each bed being minutely described in the references to that section, it is unnecessary to repeat the description here. Some of the beds contain fragments of shells, but they are very small and by no means abundant, and as I have before observed, I had searched the deposit for them many times before I found them. The points where they have been found are indicated on the section by a cross.

With respect to the rocks which have furnished the materials of the gravel, it may be observed that fragments of red and violet roofing slate and the ordinary black slate of Snowdonia, as well as red felspathic pebbles derived from the Poikilitic conglomerate which extends to this neighbourhood, pervade all parts of the mass—but there are beds in which particular kinds of fragments prevail, indicating changes in the direction and intensity of the currents that transported them. Fragments of chlorite slate, serpentine, jasper and crystalline limestone may have been derived either from the S.W. or north, as these rocks occur abundantly in Anglesey, and occupy a small tract in the S. W. extremity of Caernarvonshire. They are dispersed through all the beds as are fragments of carboniferous limestone, chalk flints, and pebbles of granite, but none of these are so abundant as in the gravel on the summit of Moel Tryfan. Fragments of the violet and red roofing slates occur as will be noticed hereafter in the detrital deposits of the promontory of Caernarvonshire, twenty miles to the south of the line, along which those rocks are found in place. They have been drifted to the neighbourhood of Pwllheli, diminishing in quantity in proportion to the distance they have been transported.

Some of the pebbles and boulders at Dinas Dinlle are as much waterworn as those of a river or beach, but most of them have undergone very slight attrition, the rounded and angular fragments are in general intermixed, but in certain parts indicated in the section, the rounded pebbles are arranged by themselves. At about 200 yards south of Dinas Dinlle, a lower cliff composed of coarse gravel exhibits no appearances of stratification. I have observed inclined stratification, though on a less extensive scale and of a less decided character in the detrital deposits covering some of the slate quarries in Nantlle Valley. It may also be seen at Killiney, in Dublin Bay, near the junction of the granite and mica slate. In those places the inclination of the strata appears to have originated in their accumulation over projecting bosses of rock. At Dinas Dinlle it may perhaps have been occasioned by the meeting of conflicting currents, one, the great northern current, sweeping along the coast, the other rushing from the Snowdonian chain, down Nantlle Valley. From Dinas Dinlle for about a mile and a half, we have a low marshy coast, a tract of diluvial land then commences with an undulating surface, varying in height from 20 to 200 feet, which fills the space between the sea and the mountains, called Gyrn Goch, and the Rifel. The greatest breadth of this tract is somewhat more than a mile. At some points it is undergoing rapid destruction from the sea—at others the destructive process is for the present suspended, for after a cliff has been for a length of time undermined a bed of shingle results from the ruins, the sea is thrown back to distances varying from 20 to 100 yards, the face of the once perpendicular cliff becomes a grassy slope, and the waves assail some other point. Where sections are afforded by the present action of the sea, the structure of this diluvial tract is seen to vary so rapidly, almost every undulation having an independent stratification, that it is impossible to give a general description. The principal sections will therefore be described in detail. The study of this tract is of the more importance, because beds of finely laminated sand and of blue pebbly clay here first make their appearance among unstratified masses of the most tumultuous character, into which they graduate both horizontally and vertically. These beds of sand and clay appear and disappear at intervals, between Dinas Dinlle and the Rifel. On the other side of that mountain they continue with considerable regularity for nearly fifteen miles.

Between Dinas Dinlle and the village of Clynog, there are but three sections in which the nature of the deposit is well displayed. The first which occurs soon after passing the Llanlyfni river is a section of a long narrow ridge or esker, composed of a confused mass of gravel embedded in a loamy base, and containing some large blocks of greywacke and hornstone derived from the neighbouring mountains. One of these blocks lying at the foot of the cliff, must weigh nearly 40 tons, and there are others still embedded, which are not much smaller.

The next section is about a mile long—a space of 300 yards, in its centre, is composed of coarse gravelly loam, like the last, with occasional horizontal streaks more gravelly than the rest of the mass. It is covered by about six inches of fine loam. This loamy deposit gradually deepens on each flank, so that for 150 yards on one side and for 250 on the other, a large proportion of the total height of the cliff consists of fine silty loam and sand.

The next section is about 100 yards long and 20 feet high—the lower 15 feet, gravelly loam, containing some coarse pebbles and boulders, covered by about 5 feet of loam, finer and more free from gravel. At Clynog, the cliff consists entirely of gravel with a few boulders, from 6 inches to a foot in diameter. This structure continues for 200 yards, the boulders continuing to increase in size and number, when bluish clay makes its appearance, at first as a thin wedge shaped bed, but it gradually increases in thickness till four-fifths of the whole cliff, or 15 feet out of 20, are composed of it. Pebbles, generally very little waterworn, and derived from various and distant quarters are dispersed through the mass, as are also finely comminuted fragments of shells. This is the first spot after leaving Dinas Dinlle where they have been found. From this point they are more regularly distributed through the detrital deposits. Above the clay is a thickness of several feet of gravelly loam covered by about six inches of fine silt.

Some indications of this blue clay, which except in the greater abundance of pebbles, and the fragmentary character of its shells, and perhaps in containing more calcareous matter, bears a strong resemblance to the London clay, first appeared on this part of the coast in the bed of Dinas Dinlle, marked N. It seems to be identical in character with that of the lower part of the cliffs at Llandulas, near Abergele, already described, of those which prevail along the south-west coast of Caernarvonshire from Porthdynlleyn to Rhiw Bay, and of those which occur to the south of Bray Head. For about 200 yards, the cliff now under description, appears to consist chiefly of this clay, but the structure is much obscured by landships.—At the end of that distance its height has increased to 30 feet, composed principally of gravel, with some streaks of red loam derived from the marl of the Poikilitic formation. In about 450 yards more, the cliff, 20 feet high, suddenly becomes a mass of boulders. The blue clay soon re-appears, first, as a thin, irregular bed, from one foot to four foot thick; but at about a mile beyond Clynog, the following is the section of the cliff:—

Surface, silty loam - - -	6	inches,
Yellowish loamy gravel - - -	5	feet,
Blue clay - - - - -	6	
Coarse gravel - - - -	12	
	23	6.

For about half a mile the structure of the cliffs is concealed by landslips and vegetation; at the end of that distance the cliff is forty feet high; its composition, where partially exhibited, coarse gravel, for about 15 feet from the top, the remainder very fine sand, containing fragments of coal: in about 100 yards more, the height of the cliff diminishes to 20 feet, the whole of which is hard, clayey gravel, covered by about a foot of fine silt: in another 100 yards a mound commences, whose greatest height is 30 feet, the upper 10 feet, consisting of loam, with boulders, the lower 20 feet of sand, with irregular patches of gravel. The height of the bed continues to increase till it reaches 60 feet, the thickness of the sand at the same time increasing, till it constitutes the entire cliff, with the exception of about four feet of gravel in the upper part, covered by a foot of fine loam. After diminishing in height, the cliff, in about 300 yards, is 60 feet high, the upper 20, gravelly loam, covered by about six inches of fine silt, the lower 40 feet sand. In about 50 yards more, gravel commences in the centre of the cliff as a wedge shaped bed, gradually increasing in thickness, till the cliff exhibits the following section:—

		Feet.
From the surface—	Loam	15
	Coarse gravel	20
	Sand	25
		60

This gravel then gradually thins off as it had commenced, the sand at the same time encroaching on the loam, till it occupies the greater part of the section. This cliff is about 900 yards long, and the length of the bed of gravel is 300.

For about 100 yards to the north of a wide ravine, which forms the bed of a small rivulet, the laminæ in the sand are much contorted, like those of mica slate. On the south side, the whole cliff, for 20 yards, consists of gravel. The blue clay then suddenly appears, and continues along the shore for a mile and a-half. This seems to have slipped down from some higher situation. At the distance of less than a furlong inland, this deposit attains the height of 200 feet, not in one cliff, but in a succession of terraces, occasioned by landslips. Under these circumstances, it is difficult to ascertain the order of succession of the different beds, or to determine which originally formed the base of the cliff. The clay certainly occupies the central portions, sometimes covered by loam, sometimes by sand, varying in depth from 4 feet to more than 20. In the gravel and loam, near the upper part of the cliff, streaks of red coloured clay occur, sometimes a foot thick, which have evidently been derived from the destruction of a portion of the new red marl.

The gravel along this part of the coast is composed of the same materials that have been described at Dinas Dinlle. After crossing the Llanlyfni River, fragments of chlorite slate become more numerous; but the chief novelty in the portion of the deposit immediately at the foot of Gyrn Goch, is the abundance and size, often reaching 18 inches in diameter, of fragments of carboniferous limestone of Anglesey, very slightly water-worn. Granitic detritus is also more abundant than it had been at Dinas Dinlle.

Between the sea shore and the foot of Gyrn Goch, is a space not more than a quarter of a mile wide. That mountain is composed chiefly of different varities of syenite, blocks of which are dispersed through the gravel, clay and loam, but they constitute the minority, the fragments of limestone being quite as numerous. The reverse of this ought to be the case, had this deposit accumulated during a long period, in a sea which bathed the sides of these mountains, or had it been shot off their flanks during some movement of elevation.

Between the low promontory of black slate, called Clogwen Morfa, and the point where the Rifel terminates abruptly in the sea, the shore for about half a mile is bounded by cliffs, 30 feet high, consisting of the following materials, in the descending order:—

	Feet.
1. Fine silty loam from	1 to 2
Its surface near the foot of the Rifel is overspread with large angular blocks of the syenite, of which the upper regions of that mountain are composed.	
2. A stratum composed chiefly of angular fragments of black slate and syenite, which form the two headlands bounding this little bay.	15
3. Blue clay, containing embedded fragments of various kinds	15
	32

Between the south-west headland of this bay, and another syenitic headland called Carreg y Lam, a noted resort of sea-fowl, is that little nook known by the name of Nant Gwrtheyrn, or Vortigern's Valley, from a tradition that Vortigern died here in concealment, after the subjugation of Britain by the Saxons. This nook is choked up with drift, consisting of clay, sand and gravel to the depth of full 200 feet. In the upper part of the deposit are some red beds derived from the destruction of the Poikilitic marl. Where the detrital deposit abuts against the syenitic headland of Carreg y Lam—large angular blocks of that rock are dispersed through the mass. On crossing the Rifel, we find the coast to the south-west of it near Porthdynlleyn, bounded by an extensive range of cliffs, consisting of finely laminated sand; and the first impression produced by these is, that the deposit has been formed by a more tranquil and gradual process than those which have been hitherto noticed. A closer examination dispels the illusion, and shews that these finely laminated beds pass both vertically and horizontally into heaps of rubbish as confused, and as devoid of stratification as any that have been described. The bay between Porthdynlleyn and the point of the Rifel called Carreg y Lam, is divided into three smaller bites, which may be called Pothdynlleyn Bay (a name generally applied to the whole) Nevin Bay and Pystill Bay.

The cliffs between Porthdynlleyn and Nevin, are from 60 to 100 feet high, and consist of finely laminated sand, with occasional seams of very fine gravel which becomes more abundant near Nevin. Patches of blue clay, four or five feet high, occur in several places in the base of the cliffs. The only spots where the deposit is seen resting on rock are at Porthdynlleyn and Nevin Points, where it rests on chlorite slate, which also protrudes through the beach in several intermediate *places.* The rock for 20 yards from the face of the cliff is free from balani; but beyond that distance it is so thickly incrusted with them that its surface is scarcely visible. The pebbles and boulders also, from the deep water of this bay, have large oysters adhering to them, none of which are found in the whole range of the detrital cliffs, neither are any balani seen adhering to the rocks on which they rest. The rock, on the contrary, either presents a weathered, or a slightly water-worn surface at the point of contact. Near Nevin, a hollow in the chlorite schist, only a few feet above high water mark, is filled with angular fragments of that rock, mixed with a few partially worn pebbles from more distant localities, the whole surmounted by sand and gravel.

Between Nevin and Pystill, the gravel which had at first been fine and only in occasional seams, becomes coarser and more abundant, and the sand frequently passes into loam. The gravel is distributed in irregular masses, and the laminæ of stratification, both in the gravel and the sand, sometimes much contorted. At Pystill Point the deposit rests on Syenite, which exhibits the same absence of marine incrustations beneath the diluvium, and the same abundance of them between high and low water-mark that has been noticed. The same remark applies to the whole coast which remains to be described.

The fragments of which the gravel of these cliffs is composed are but slightly water-worn. They consist principally of chlorite slate, jasper, serpentine, crystalline limestone, and greywacke slate, all of which are the foundation rocks on which this deposit rests. They are also found in places in Anglesey, lying to the north-west, and in all probability constitute the bed of the intervening sea. The gravel also contains fragments of the syenite of the neighbouring Rifel, pebbles from the Poikilitic conglomerate of Caernarvonshire, and of the violet roofing slate of Snowdonia, together with fragments of the Carboniferous limestone of Anglesey.

In Pystill Bay, the blue clay occupies a considerable portion of the cliffs from their base upwards, passing both vertically and horizontally into loam and gravel. Syenitic fragments, both angular and slightly abraded, become numerous as we approach the Rifel; and near the foot of that mountain, constitute the greater part of the mass. Blocks of syenite, three or four feet long are also dispersed through the loam, often in positions into which they would not have settled from the force of gravity. This circumstance, which is of frequent occurrence in the northern drift of Wales, has also been observed by Dr. Scouler, in the boulder deposits of Ireland. Fragments of shells occur at intervals in every part of the deposit. In the sand they are very finely comminuted, and there are no layers of shells following laminæ of stratification, and thus indicating gradual formation. From Porthdynlleyn, to the foot of the rocky promontory called Braich y Pwll, at the south-western extremity of Caernarvonshire, and opposite Bardsey Island, the detrital deposit may be generally seen resting on chlorite slate, with beds and veins of serpentine, crystalline limestone, granular quartz, and jasper. The cliffs are from 40 to 100 feet high, not often reaching the latter altitude; the rock sometimes constituting full half of the entire cliff, sometimes being nearly on a level with high water-mark.

From Porthdynlleyn to Porthcolman, the diluvial deposit consists principally of sand and loam; occasional patches of the blue clay are interposed between them and the rock; but this member of the deposit is very inconstant, and sand, loam and gravel are more frequently seen in contact with the chlorite slate.

From Porthcolman to Maen y Melin, the clay occurs with greater regularity in the base of the cliffs, and the loam becomes more argillaceous.

In the sandy deposit of this part of Caernarvonshire, we frequently meet with concretionary sandstone (17), sometimes forming large masses of a botroidal structure, and the gravel also is occasionally cemented into a conglomerate by a base, partly argillaceous, party calcareous.

Pebbles of coal which first made their appearance in a sandy cliff near Clynog, are very abundant to the south-west of the Rifel; and on Rhos Hirwan, near Carreg, occur, at about three feet from the surface, in a seam from three to four inches thick. This drifted coal has given rise to many fruitless trials for that mineral, some of which are now in progress. Shafts are sunk through the diluvial deposits, and sometimes continued into the chlorite schist, or black schist, on which they rest, and on which they might be seen resting in coast sections, without the expense of sinking shafts to prove it. Of the absurdity of such trials, it is as impossible to convince those unacquainted with the order of succession of the strata composing the earth's crust, as it is unnecessary to point it out to geologists.

But while labour and money are thus wasted in searches for mines of coal, where they never can be found; other sources of wealth within the reach of the land-owner and farmer, are too much neglected. The sandy and loamy surface of this district forms a light, dry, and deep soil, admirably adapted to the growth of barley and turnips, and yet, the latter are scarely cultivated, except on a small scale, by a few of the gentlemen. The blue clay which is generally to be found in the vicinity, if applied as a dressing to the more sandy portions of this tract, would greatly improve them, and yet, I cannot learn that it has ever been used for that purpose. I have found in some specimens that I have tried, 20 per.cent. of calcareous matter. It is a clay scarcely more calcareous than this which has so completely changed the face of large districts of the county of Norfolk, and has raised the annual value of some of its blowing and barren sands from three shillings an acre to more than twenty.

On crossing the low ridge near Carreg, which terminates in the Promontory of Braich y Pwll, we find in Aberdaron Bay, between the headlands of Penykil and Trwyn Penrhyn, a range of diluvial cliffs about a mile long. These cliffs are from 60 to 80 feet high. Towards the centre of the bay, the lower half consists of clay, the upper of loam, with a few boulders of different sizes dispersed through it. Towards the western side they are composed chiefly of sandy loam, and the clay seldom attains the height of 20 feet above the beach. At the extreme western point where the detrital deposit approaches the rock of the bounding headland, there is no clay, but the loam containing fragments of shells (*d*) rests on a breccia *en place*, (*c*) and ancient talus composed of angular fragments of the subjacent rock, (*b*) (Section viii.) At the eastern side of the bay, the cliff 80 feet high is composed of clay, with about five feet of loam at the surface, and has a similar angular breccia *en place*, between it and the rock.

Crossing Mynydd Rhiw, another bare rocky promontory, we find a range of diluvial cliffs three miles long, extending to the neighbourhood of Llanengan, and bounding the shores of Rhiw bay, which is generally laid down on the maps, under the name of Hell's Mouth. These cliffs consist chiefly of clay, with a thin covering of tenacious loam. Near Rhiw, they are nearly 100 feet high, thence gradually declining to 15 or 20 feet near the eastern extremity where the clay is covered by alluvial deposits and blown sand.

These cliffs are rapidly yielding to the action of the waves, partly from their exposure to an open sea, and the prevailing winds, partly from the comparative scarcity of boulders and gravel in the formation, from which cause the ruins do not form accumulations of shingle which retard the erosive process.

On some parts of the shore of this bay, landslips have occasioned an undercliff about 15 feet above the ordinary action of the highest tides, and on its surface, the storms of the last winter have lodged considerable quantities of shingle, but the destruction of the under cliff will prevent this accumulating in sufficient masses, to be mistaken for a raised beach, which might happen on a rocky coast of the same height similarly exposed.

In the clay of these cliffs, I have found fragments of the hard chalk of the county of Antrim, (18) both worn to smooth pebbles, and also only slightly abraded. So long ago as the year 1831, I had met with chalk flints in the gravel of Moel Tryfan, which I then stated, could have come from no nearer source than the county of Antrim; I subsequently met with them in the gravel of other parts of Wales, and I was beginning to doubt whether they had been transported from the north of Ireland, because they were unaccompanied by any fragments of the hard chalk, and there appeared no reason why the one should not have borne the transport as well as the other; whereas soft chalk like that of England, might have been destroyed by attrition, while the flints would remain uninjured. On examining the cliffs at Howth, soon after Dr. Scouler had discovered shells there, the greater abundance of flints contained in them, convinced me that those found in Wales must have been derived from Ireland. Dr. Scouler at that time was not disposed to regard them as chalk flints, but as nodules derived from the trap rocks of the neighbourhood, until I produced to him some pebbles of the chalk from Howth; and a few days afterwards, we found some larger fragments of the same rock in the blue clay of Bray. In 1836, I discovered in the cliffs at Rhiw, some fragments of the hard chalk of the county of Antrim, now in the possession of Dr. Buckland, which were larger than any of those on the table, (rather more than an inch in diameter) and I have lately met with two or three small fragments in the clay of Porthdynlleyn bay.

The clay of this part of Caernarvonshire also contains fragments of a black limestone, (19) having a greater resemblance to the calp of the neighbourhood of Dublin, than to any of the beds of the Carboniferous limestone of Anglesey, that I am acquainted with. These fragments of black limestone, first appeared with the appearance of the blue clay in the cliffs, between Clynog and the Rifel. They were there mixed with fragments undoubtedly derived from the limestone of Anglesey, but these latter become more rare, and the black limestone resembling the calp more abundant, as we approach the S. W. extremity of Caernarvonshire.

Towards the base of the clay cliffs, as well as in their upper part, are seams, a few inches thick, of laminated sand (20), containing small pebbles of wood and coal, and also finely comminuted fragments of shells.

The sections of the detrital deposits along the whole coast, from Clynog to Rhiw, contain fragments of marine shells (21);

but the only whole specimens I have obtained have been from the latter place. Indeed, the northern drift, from Chester to the south-western extremity of Caernarvonshire, has afforded only the following whole specimens, or large and well-characterized fragments:—

Talargoch—a whole specimen of *Purpura Lapillus.*

The cliff near St. Asaph—three of the upper whorls of *Pterocera Pes pelicani.*

Near Nevin—the umbo, with the hinge teeth of *Cyprina Islandica.*

Aberdaron Bay—a nearly whole valve of *Tellina Solidula.*

Rhiw Bay—two or three both of the upper and lower whorls of *Turritella Terebra;* and three whole specimens of *Fusus Bamfius.*

Dr. Trail discovered, many years ago, magnetic iron sand oozing out of a bank of diluvial clay, opposite the town of Liverpool; and I have met with it under similar circumstances in the following localities: on the shores of the Menai, near Plas Llanfair; at the foot of Gyrn Goch, between Clynog and the Rifel; in Nevin Bay; in Porthcolman Bay (22); in Aberdaron Bay, where it occurs in considerable abundance, and where it was pointed out to me as an indication of coal; in Rhiw Bay; and at Killiney, near Dublin.

The shelly detrital deposits of Lleyn, as the horn of Caernarvonshire is called, are not confined to the coast, but are spread over the interior. In order to explain the mode of their distribution, it must be premised, that one main ridge of hills, having an elevation no where exceeding 1,800 feet above the sea, runs down the centre of the promontory, from the Rifel to Braich y Pwll; from this central ridge, spurs are thrown off in several directions, dividing the district into basins filled with these diluvial deposits. The names of the principal eminences of this central ridge are Garn Nevin (a shoulder of the Rifel), Garn Madryn, Mynydd Cefn Amwlch, and Bryn Mawr, which terminates in the headland of Braich y Pwll.

Between Garn Nevin and Garn Madryn there is a depression through which the sandy deposit of Nevin Bay has passed, filling what may be called the Pwllheli Basin, on the eastern side of the central ridge; and, when good sections are obtained, fragments of shells and pebbles of coal are found in this basin in the interior of Lleyn. The space which extends from the Rifel to Maen y Melin, and is bounded by the central ridge on the east, and the sea on the west, may be called the Nevin Basin. It is filled chiefly with sand and loam, which south-west of Porthcolman, becomes more argillaceous. It has crossed the central ridge at a depression between Mynydd

Cefn Amwlch, and Braich y Pwll Head, and fills the basin of Aberdaron, bounded on the east by Rhiw Mountain.

From Garn Madryn, one spur runs to Mynydd Rhiw, and another by Llanbedrog, to the point of Penrhyn Du, opposite St. Tudwal's Islands, thus bounding the Rhiw Basin, which is filled almost wholly with clay.

Immediately to the south of the Rifel the detritus is chiefly local and angular, derived from that mountain, mixed near Llanhaiarn, and thence to the neighbourhood of Pwllheli with fragments of the violet roofing slate of Snowdonia, which have crossed the Rifel Ridge at a comparatively low point, the same point at which the Pwllheli Road crosses it.

The coast of Cardigan Bay from Llanbedrog to Criccieth is in general low and affords no diluvial sections of any importance except at the foot of the rock on which Criccieth Castle stands.—(Section vii.) Here is a detrital cliff, the greatest height of which near the castle is about 50 feet, from which it declines in about the length of 150 yards to 10 or 12 feet. The fragments composing it are chiefly greenstone and black-slate, which have been derived from the country lying to the northward, between Criccieth and the Snowdonian Chain. The intervening surface is thickly covered with boulders of the same rocks. Parts of it may almost be said to be paved with them. On a common called Rhos Lan, there must be a boulder to every ten square yards, and some of them cannot weigh less than 20 tons.

In the cliff at Criccieth, which has a loamy base, we find a case of local detritus derived from the north, in which neither shells occur, nor the detritus of distant rocks, which usually serve to identify the northern drift.

The base of this cliff is washed by the waves of Cardigan Bay, and it is difficult to account for the absence of shells on the hypothesis of its being a raised beach or sea bottom; but a glance at the map is sufficient to explain these circumstances on the supposition of its having been spread by a rush from the north over pre-existing land having nearly its present configuration; for we see that the whole mass of the Snowdonian Mountains is interposed between Criccieth, and the northern sea, and region of granitic rocks.

Criccieth Castle stands on quartz rock, in some parts exhibiting rude traces of stratification, in others a prismatic structure. Very few fragments of this rock are found mixed with the partially worn pebbles of greenstone and black slate dispersed through the loamy mass; but between the rock and this deposit of loam is an ancient talus (*b*) from four to five feet thick, composed entirely of angular fragments of Quartz Rock.

From this ancient talus, at about three feet above the beach, a tongue (*c*) of the same angular detritus runs off into the deposit of loam, with pebbles and boulders(*d*). This tongue is about two feet thick in its widest part, and thins off to a mere line in the length of 15 feet. It contains a few pebbles of greenstone and black slate partially water-worn, mixed with the angular fragments of Quartz Rock. There appears no mode of explaining these phenomena except this: that the Castle Rock was elevated above the sea; that it had a weathered surface, and that a talus had formed at the foot of it, over which the loamy deposit, containing the detritus transported from the north, accumulated so rapidly as to prevent the dispersion or attrition of the mass of angular fragments.

The extension of the small tongue of these angular fragments into the loamy mass, precludes the supposition of their having been produced by movements of elevation, subsequent to the formation of the diluvial deposit.

About a quarter of a mile east of the castle there is a bank of loam about twelve feet high, through which are dispersed boulders of trap and black slate derived from a little distance to the north, similar to those in the castle cliff, only more numerous and of a smaller size.

The only remaining diluvial section on this part of the coast, which it is necessary to notice, occurs on the opposite side of Cardigan Bay, at Harlech Castle which stands on a cliff about 60 feet high, composed wholly of local detritus derived from the part of Merionethshire immediately to the north of it, and containing, though close to the sea, no fragments of shells. For an explanation of this, as in the case of Criccieth, I again refer to the map, and point to the mass of the Snowdonian Mountains, protecting it on the north. Mr. Murchison would probably see in these phenomena, as in the local nature of the detritus of South Wales and Siluria, proofs of the elevation of this part of the coast, and of its conversion into dry land while Lancashire, Cheshire, Salop, and Worcestershire, as well as the northern and western skirts of the Cambrian Chain from Chester to Rhiw Bay, lay beneath the sea in which the northern drift was slowly accumulating.

In the year 1831, when I received informations from some of the quarrymen of the neighbourhood, that the gravel and sand of Moel Tryfan, contained marine shells the sides of the excavation which had disclosed this fact had fallen in, and I was only able to obtain specimens of shells and of granitic detritus from the old rubbish by which the section was obscured, and by partial diggings in the mass of fallen gravel. Since then another company having taken a lease of the ground have re-opened the excavation in search of slate rock, and their operations have strengthened the evidence in favour of the rapid accumulation of this shelly gravel, by the sudden, violent, and transient action of the sea.

They have made a section of this gravel which has exhibited its structure and depth, and has exposed to view the rock beneath it. The excavation is about 70 yards long, and gradually deepens from nothing to about 30 feet. The upper 15 feet in the deepest part consists of sand, loam, and gravel, confusedly mixed, without shells, but having boulders of the felspathic rock of the summit of Mynydd Mawr, and occasionly pebbles of granite dispersed through it. Beneath this occur, about 15 feet of gravel, sand, and clay, in alternating seams, having a curved lamination, and containing fragments of shells and granitic detritus, (23), in greater abundance mixed with local detritus, the mass of which is but slightly water-worn. Below this we find about 4 feet of sand and loam, without shells; then, about two feet of angular detritus (24), of the subjacent slate rock, which exhibits one of those cases of ancient weathering, noticed in the first part of this paper, (section 1). The pebbles of carboniferous limestone in the deposit, exhibit no traces of lithodomous perforations (25)

The floor of the excavation was a few feet above the level of the rock, which was reached by sinking on it.

The shelly deposit covered about 35 yards of the length of the excavation.

The western side of the section is similar to the eastern, except that the superficial deposit of sand, without marine remains is rather deeper; and that in the midst of it, there occurs a patch about a foot long, and 18 inches deep, of angular fragments of slate, among which are a few broken shells.

This excavation unfortunately was carried on during the winter, and consequently, few opportunities were afforded of finding whole shells. I obtained, however, one specimen of *Fusus Bamfius* (26), several of which had been found here before; and also a nearly perfect shell of *Fusus Antiquus* (27), which had been crushed into numerous fragments, and re-united by a cement of carbonate of lime. This must have been occasioned by the shell having been crushed, while it contained the animal, whose body retained the fragments together till they were re-united. Besides Moel Tryfan, Moel Faban, (near the Penrhyn quarry,) and Dinas Dinlle, there is only one other spot in the seventy square miles between the Menai and the summit of the lowest ridge of the Snowdonian mountains, in which marine remains have been detected, and that is in a cutting on the Nantlle railway, near the Dinas Tunnel, at the height of about 100 feet above the sea, and distant from it about 2 miles. This is the only section on this railway, 9 miles long, and no where rising much more than 300 feet above the sea, in which marine remains have been found, although the structure of many diluvial mounds has been laid open in its course.

In all the localities where fragments of shells have been found in the northern drift, whether in England, Ireland, or Wales, they occur in very different states on the same spot; some of the fragments have lost their gelatine, and adhere to the tongue, but many retain their translucency, and will not yield to the knife, and some have not lost their colour and their nacre.

Two other excavations have been made on Moel Tryfan, about 1500 yards to the south-west of that yielding the shells, and on the southern slope of the mountain, but they contain no marine remains. One of these excavations exposed to view about 15 feet of angular fragments, and of bent and shattered tops of slate rock. The angular fragments become smaller towards the upper part of the mass, and are covered by from 4 to 5 feet of loam, containing partially abraded boulders of compact felspar, derived from the summit of Mynydd Mawr, and among the angular fragments of slate are two or three of the same kind of boulders. Another excavation, at a little distance, has rock on its northern side; and on its southern side, a mass of angular fragments of that rock, which in this case is greywacke sandstone, the whole surmounted by loam with pebbles, like that of the last section, only much thinner.

These circumstances appear inexplicable on the supposition of long submergence and gradual accumulation; but favourable to the hypothesis of sudden, violent, and transient action, the commencement of which shattered the weathered surface of a bare rock; and heaped the fragments together, its close accumulating the loam, and the boulders of somewhat more distant rocks.

From the facts which have been recorded in the preceding pages, I draw the following conclusions:—

1. That throughout the region of the northern drift, both on the eastern and western sides of the Cambrian chain, the absence of those phenomena which are adduced as proofs of the gradual formation of other subaqueous strata, as well as the indications of the sudden and transient action of water, afforded both by the deposit itself, and by the rocks on which it rests, render it necessary to make a distinction between

this deposit and raised beaches and sea bottoms. The fact of its being occasionally stratified is much insisted on, by those who contend for its gradual formation; but there is this distinction between the stratification of the northern drift and that of formations, which are undoubted sea bottoms, that, in the latter, the stratification is persistent over considerable spaces, while in the former it is not. Among the regular strata, it is by no means uncommon to find the same deposit extending for 200 or 300 miles, with only slight modifications of its mineral character: in the diluvial deposits it is very rarely that we can trace the same bed for 300 yards. Many remarkable instances of these rapid changes have been described between Clynog and the Rifel.

2. The phenomena of Cefn Cave prove, that a portion of this northern drift, which cannot be separated from the rest of the deposit, accumulated on dry land of sufficient extent, to support the larger mammalia.

This, according to Mr. Murchison, would, if established, be one of the greatest anomalies attending the boulder deposit, while, according to Professor Phillips, it is a point of great importance among the many partial truths which must be established before we can look for any general theory of diluvial deposits; though, as he elsewhere observes, "the principal difficulties of the question relating to the agencies concerned in the dispersion of diluvial detritus, would not be removed, nor perhaps even diminished, but rendered more definite, and therefore, more within the scope of Geological research, could we be quite certain of the fact, whether this mass of heterogeneous materials was deposited by great inundations on the land, or thrown into the sea.*"

3. Its accumulation on dry land must have been occasioned by the sea having been thrown on the land, or by the land being suddenly submerged and re-elevated, or by a combination of the two agencies. The land, moreover, must have remained submerged too short a time for limestone to be drilled by lithodomous molluscs, for the remains of successive generations of testacea to accumulate on the spots where they lived and died, for the mass of the detritus to be converted into smooth pebbles, or for the fragmentary matter to arrange itself according to magnitude and specific gravity; and these conditions preclude the supposition of its having been formed by causes now in action, and acting with their present intensity, although in the oscillations of land and sea produced by modern earthquakes, we may see analogous agencies acting with minor force.

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* Phillips, in Lardner's Cyclopedia: Geology, vol. 1. p. 297.

4. If the formation of this northern drift was occasioned by the sudden submergence and re-elevation of pre-existing land, it would appear, from the great areas over which fragments of the same rocks have been dispersed, that portions of the earth's surface of considerable extent have been subject to submergence at the same time.

5. If the British Islands have been thus suddenly submerged, and suddenly re-elevated after a short submergence, it would appear, from the cases on record round the shores of both islands, in which the northern drift rests on ancient beaches, and in which estuary deposits of gradual accumulation cover northern drift, that England and Ireland sank as separate islands, and that, when they re-emerged, the ancient shores of each of them were very nearly re-established; the previously existing coasts being, to a certain extent, respected by these oscillations of the land, in the same manner that the present general configuration of hill and dale modified the distribution of the detrital matter in its passage over the land, by producing minor currents subordinate to the great rush of water from the north.

Lastly, we have not yet sufficient evidence to enable us to decide on the causes by which the northern drift was produced. The most probable solution of the difficulties of the question seems likely to be found in extensive and violent oscillations of the crust of the earth; movements in the bed of the northern ocean throwing waves over the land, and these waves being accompanied by sudden depressions and re-elevations of the latter, which thus aided the moving power of water, and lodged vast boulders of distant rocks, in most cases without the aid of ice, in the extraordinary situations where they are now found.

With respect to the diluvial department of geology, we are at present in the same position that this science in general was before the formation of the Geological Society of London —we want facts. Before we can frame any general theory of diluvial accumulations we must ascertain how much of that boulder formation, which covers so large a portion of the northern hemisphere, can be proved by the evidence of its organic remains, marine, as well as terrestrial, to belong to the same geological epoch; and how much again, belonging to the same epoch, is strictly contemporaneous. We shall then know where to look for the centre or centres of disturbance. To the collection of facts, then, let us actively apply ourselves, each retaining, provisionally, his favourite theory; for a theory, as Professor Sedgwick has observed, forms an excellent nucleus round which to marshal facts. All that is required of us is that we should keep our eyes constantly open, not only to phenomena favourable to the hypothesis which we have adopted, but also to those which are unfavourable to it; and that when we meet with them we should have sufficient candour to record and to proclaim them.

ANALYSIS OF SOME IRISH DOLOMITES.

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At the last meeting but one of this Society, a very interesting paper was communicated by Doctor Scouler upon the origin of dolomitic limestones, which gave rise to a good deal of discussion, in the course of which it was incidentally observed by me, that many calcareous rocks considered as magnesian, contained but a trace of that earth, and that therefore an accurate chemical analysis of the various limestones viewed as dolomitic, by geologists, appeared absolutely necessary as a preliminary to our forming a correct judgment respecting the theories which have been put forward to explain the manner of their production. A distinguished member of this Society, Mr. Griffith, seemed to concur in this opinion, and with his usual liberality, proposed furnishing me with specimens of magnesian limestones from different Irish localities, with a view to their accurate chemical examination. Some of the more remarkable of these, have been already submitted to analysis, and although the investigation is not as yet quite completed, I have been led to believe that the results at which I have already arrived, would interest the Society, and I shall therefore, without further preface, proceed to bring them under the consideration of this meeting.

The separation of lime from magnesia is, as is well known to chemists, a problem of considerable difficulty, though one of perpetual recurrence in analytical operations. A variety of methods have been proposed, and practised with more or less success. Thus, Mr. Phillips, with a view to the direct estimation of the lime, recommends that both earths be converted into sulphates, and that the sulphate of magnesia be washed away by a saturated solution of sulphate of lime. This method, though theoretically correct, is in practice difficult of execution, for, should the temperature of the solvent vary during the washing, the sulphate of lime which we wish to insulate, will be augmented or diminished.

Others have recommended the percipitation of the lime by sesquicarbonate of ammonia, or by the fixed alkaline bicarbonates; but by these viagents, the entire of this earth cannot be thrown down, owing to the solvent action of carbonic acid, upon carbonate of lime. The former reagent indeed answers tolerably well, provided it be previously mixed with a little water of ammonia, but, even with this precaution, it cannot be considered as accomplishing the desired object in a perfect manner.

The separation of the earths has also been attempted by converting both into muriates, and exposing these to a strong red heat, so as to decompose the muriate of Magnesia. Mr. Tennant also, after the application of the heat, determined the amount of the free magnesia by a peculiar process. He added a known quantity of muriatic acid, so as to re-dissolve this earth, and estimated the amount of free acid by ascertaining experimentally the quantity of pure corbonate of lime, which the solution was capable of dissolving. This process, though circuitous, is in principle correct; but as it is very difficult to decompose by heat every vestige of the muriate of magnesia, it will generally give for this earth a result lower than the truth.

The method at present most generally employed, consists in adding to a cold and neutral solution of the two earths in muriatic or nitric acid, a proper quantity of oxalate of ammonia, letting the whole rest for twelve hours, drawing off the supernatant solution, which contains the magnesia, and washing the precipitate repeatedly upon a weighed single, or upon a double filter. The filtration must not be proceeded with immediately after the precipitation of the lime, for if so, some of the oxalate of this earth would almost certainly pass through the filter.

This method, as far at least as respects the separation of the lime, is perfect; and when there is no third substance present the magnesia may obviously be inferred from the difference between the weight of the lime and of the mixture of it with magnesia supposed to have been previously ascertained. But to insulate the magnesia, or recover it from the washings of the oxalate of lime, is a thing of extreme difficulty. Boiling with carbonate of potash is very far from being an accurate method, even though we evaporate to dryness; for during the subsequent washing, a very considerable proportion of the magnesia is carried away by the water. In estimating the magnesia, I have always converted it, as shall be presently described, into a sulphate, and weighed it in this state, and I do not think that an accurate result can be obtained in any other way. If we be content with estimating the relative proportions of the two earths, and do not aim at separating them from each other, the thing may be done in the following manner:—

Let the weight of the mixed earths, as determined by experiment, be a, and that of their sulphates b. Let also x represent the lime, y the magnesia, and m and n the ratios between the respective atomic weights of lime and magnesia, and those of their sulphates. We shall then obviously have the two following equations:—viz.

$$x+y=a \quad \text{and}$$

$$mx+ny=b$$

from which we readily deduce—

$$x=\frac{b-na}{m-n}$$

$$y=\frac{ma-b}{m-x}.$$

The course which I pursued in all the subsequent analyses was the following:—A portion of the stone perfectly sound, or which did not at all events *appear* to have undergone any alteration, was selected, reduced to a fine powder in an agate mortar, and then accurately weighed in a counterpoised flask of green glass having a flat bottom, and of a conical form. It was now acted upon by muriatic acid, and when effervescence had nearly ceased, a little nitric acid was added in order to peroxidize the iron. The solution having been rendered nearly neutral by cautious evaporation, and diluted with distilled water, a solution of water of ammonia was cautiously dropped in until the liquid became perfectly neutral, care being taken to add as slight an excess of the alkali as possible, lest, by reason of the carbonate of ammonia, which it almost always includes in small quantity, some of the lime should be precipitated. The ammonia precipitates the peroxide of iron, and it and the silex having been first collected, washed, and weighed together, their separation was subsequently accomplished by muriatic acid, which dissolves the former alone. The amount of the peroxide thus obtained was finally reduced to carbonate by calculation.

To the washings of the iron and silex, and which contained the lime and the magnesia, such a quantity of ammonia was added as would be adequate to precipitate the whole of the lime, if the stone was exclusively a carbonate of this base, and the precipitate (oxalate of lime) having been allowed twelve hours for subsiding, the supernatant solution was drawn off, and the oxalate collected, and well washed upon a double filter. The precipitate, first dried in an oven at a temperature of about 250° was then exposed to a low red heat, by which it was reduced to carbonate of lime, in which state it was weighed. Before weighing, however, it was moistened with carbonate of ammonia, and again brought to dryness at an obscure red heat, lest during the decomposition of the oxalate any of the carbonic acid may have been expelled. The washings containing the magnesia in the form of oxalate mixed with muriate and oxalate of ammonia, were next supersaturated with sulphuric acid, evaporated to dryness in a balanced porcelan capsule, and then exposed to a low red heat, by which the sulphate of ammonia was volatilized, the oxalic acid resolved into carbonic acid and carbonic oxide, and the anhydrous sulphate of magnesia left behind. This latter being weighed the amount of its base was easily inferred, and brought by calculation to the form of carbonate. Six distinct magnesian limestones were analysed upon this plan, with the following results, which, for greater clearness, I have thrown into a tabular form.

	Howth.	Knocknaree.	Kilkenny.	Ballyshannon.	Murlough Bay.	Donegal Marble.	County Meath.
	S.G.=2.801	S.G.=2.760	S.G.=2.750	S.G.=2.740	S.G.=2.388	S.G.=2.714	S.G.=2.810
Carbonate of Lime...	15.96	16.21	14.16	16.13	29.17	29.17	15.48
Carbonate of magnesia	12.61	13.53	13.74	11.62	0.70	0.70	12.52
Carbonate of Iron ...	0.98	0.23	0.13	0.72	0.00	0.00	Fe_2O_3 SiO_3 } 3.67
Silex........	0.45	0.00	0.00	3.10	trace	trace	
	30.00	30.00	30.00	29.60	29.87	30.00	31.67

The county Meath specimen I received since the analysis of the others was completed, from my friend Mr. Mallett, with a note, of which the following is an extract:—" I send you herewith a specimen of the magnesian limestone, and also one of the (presumed) common limestone which joins the former. It would be interesting to see whether the latter contains any notable quantity of magnesia. The tract from which this is taken, is, I am inclined to think, unknown to geologists. It is about three miles long, by one inch wide, and lies between

Ashbourne and Navan. It contains several small veins of sulphuret of copper with pyrites."

The Howth magnesian limestone, which is of a yellowish colour, and has an imperfectly crystalline structure, occurs, as is well known, imbedded in ordinary blue limestone situate in the immediate vicinity of quartz and clay slate, the rocks of which that peninsula is chiefly composed. With respect to the geological position of the other dolomites, our late president, Mr. Griffith, has supplied me with the following information:

"The dolomite of Ballyshannon occurs in the form of an irregular stratum amongst the lowest beds of the carboniferous limestone close to the contact of mica slate passing into gneifs."

"This specimen (the one from Knocknaree) is a portion of a bed of dolomite which occurs interstratified with subcrystalline grey limestone, on the summit of Knocknaree mountain, two miles south-west of the town of Sligo. It belongs to the upper division of the carboniferous limestone series."

"The dolomite of Kilkenny occurs on the northern bank of the river Nore, about three miles below the city of Kilkenny. It occurs in veins and irregular beds in the most of the carboniferous limestone. The dolomite sometimes contains angular fragments of carboniferous limestone."

The specimens from Murlough bay, and the Donegal marble, contain but very small quantities of magnesia, and can scarcely be considered dolomites. The former possesses a very peculiar structure being composed of minute crystalline grains, which cohere so slightly that they may be separated from each other, and the stone reduced to a granular powder by pressure with the nail, or between the finger and thumb. It is also distinguished by a specific gravity lower than that of any other calcareous carbonate with which I am acquainted.*

The four remaining specimens are genuine dolomites, and are composed of an atom of carbonate of lime and an atom of carbonate of magnesia, a little of the latter being replaced by carbonate of iron. That such is their real constitution is strikingly shown by the following table, the numbers in the first column of which represent the carbonate of magnesia, which each specimen should contain upon this hypothesis; those in the second, the quantity of carbonate of magnesia experimentally obtained, and those in the third, the carbonate of magnesia equivalent to the carbonate of iron found by analysis.

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* It was subsequently ascertained that the lowness of this result was due to the presence of air, for upon placing a specific gravity bottle filled with water, and containing some fragments of the mineral, under an exhausted receiver, a prodigious number of bubbles escaped, and the density rose to 2.666 in one experiment, and to 2.675 in a second. During the escape of the air the fragments crumbled into a tolerably fine sand.

	CO_2+MgO by Calculation.	CO_2+MgO by Experiment.	CO_2+MgO Equivalent to CO_2+FiO_2	
Howth…………	13.50	12.61	0.72	13.33
Knocknaree…….	13.71	13.53	0.18	13.71
Kilkenny……..	13.64	13.74	0.09	13.83
Ballyshannon….	11.97	11.62	0.53	12.15

The numbers in the last column, which are the sums of the corresponding ones in the two preceding are, it will be seen, so very nearly equal to the numbers in the first column, that no doubt whatever can be entertained of the truth of the hypothesis upon which the latter have been calculated.

In this result, however, there is nothing novel. Dr. Thomson in his elaborate work on Mineralogy, (vol. i. p. 181,) states, that he has analyzed several specimens of magnesian limestone, both crystallized and granular, and in every instance found the carbonates of lime and magnesia present in the ratio of atom to atom; and five out of eight specimens analyzed by Berthier, (Ann. des mines, 2d series, iii. 27,) had a similar constitution. Of the remaining three one contained two, and another four atoms of carbonate of lime associated with one of carbonate of magnesia; and the remaining one, three of carbonate of lime, and two of carbonate of magnesia. Mr. Smithson Tennant, in his very interesting paper in the Philosophical Transactions for 1799, "upon the different kinds of lime employed in agriculture," gives the relative proportions of the two earths in the calx procured by burning eleven different kinds of magnesian limestones, all of which, allowing for a slight deficit of magnesia due to the imperfection of the method employed, would appear to have the same composition with the dolomites which I have examined.

A minute account of the individual characters of the different specimens, whose composition is given above, would not be interesting, and would convey but little instruction. I may, however, enumerate here the circumstances by which, independent of analysis, we are enabled to distinguish a dolomite from ordinary limestone. In the first place then, the dolomites are, generally speaking, more highly crystalline than common limestone, and their fracture exhibits more distinctly the faces of the rhombohedrous. In the second place, their density is invariably higher than that of the purer calcareous carbonates. The Donegal marble, for example, has only the specific gravity of 2.714, while that of the Ballyshannon dolomite, whose density is lowest, is 2.740. In the third place, they dissolve much more slowly in the dilute acids than ordinary limestone. This is a character of the dolomites universally known. While dissolving, however, I have observed a circumstance which appears to me characteristic of them. A fragment of one of them when acted upon for some time breaks up into a number of minute particles, constituting a coarse crystalline powder, which would appear to arise from the prior solution by the acid of the cement by which the minute rhombohedrous were previously held together. This, it is scarcely necessary to say, does not occur with limestone, or even with granular marble. Lastly, a dolomite will, weight for weight, yield a larger amount of carbonic acid and suffer of course a greater loss in burning, than ordinary limestone, a circumstance obviously due to the fact of the atomic weight of magnesia being less than that of lime.

I shall now venture upon a few remarks upon the origin of dolomites, a point which has been much discussed among geologists, and is even at present far from being decided. Are they original formations, or are they to be classed amongst metamorphic rocks? and, if they be altered limestones, from what source have they derived their magnesia, and what is the agent which has been instrumental in its introduction?

That they are original formations may be very plausibly contended, and upon various grounds. In the first place they include organic remains, as has been particularly observed by M. De la Beche, of the dolomite of Nice, though never in the same quantity with ordinary limestone; and it is certainly very difficult to conceive how such fossils could have retained their shape after the operation of the forces assumed in the metamorphic hypothesis.

In the second place their composition, as we have seen, is perfectly definite; a fact scarcely intelligible if we suppose that the magnesia was casually introduced from some external source.

The opposite theory, however, has its advocates; and would even, at the existing period, appear to be the more popular of the two. Von Buch, as is well known, relying principally upon phenomena exhibited at the mountain of San Salvador, on the lake Lugano, contends that the dolomites which occur in the vicinity of augitic porphyries are the result of the action of vaporized magnesia, expelled from these latter rocks, upon ordinary limestone; while others, and in particular Doctor Scouler, consider the metamorphosis in question to be effected by the afflux of magnesia dissolved in water impregnated with carbonic acid. Of these two methods of accounting for the introduction of the magnesia, I cannot help thinking the latter by much the more probable. I am unable, I confess, to understand how almost any degree of heat could render magnesia gaseous; for this can certainly not be accomplished by the most intense artificial heat which it is in our power to produce. But there is another argument which has occurred to myself, and which certainly appears to me quite fatal to this hypothesis. In two of the dolomites which I have analyzed there is a considerable quantity of silex—1.49 per cent. in that from Howth, and 10.32 in that from Ballyshannon. Now this silex exists merely as sand mechanically intermixed, and not in combination with either of the bases; a thing which certainly could not be, as shall presently be shown, if the stone was originally subjected to a very high temperature. At a high heat a silicate of lime or magnesia would be formed, and when the dolomite was acted upon by an acid, and the solution evaporated, the liberated silex would gelatinize; a circumstance which is never observed to occur.

In the other method of explaining the presence of the magnesia, nothing is assumed which is inconsistent with our actual knowledge. Carbonic acid will certainly dissolve carbonate of magnesia as well as carbonate of lime, and we can at least understand how the dolomization of limestone may be thus accomplished. I would merely suggest, as an extension of this hypothesis, that, as many limestones contain a small quantity of magnesia, their conversion into dolomites may sometimes be accomplished, not by the addition to them of magnesia, but by the removal of carbonate of lime, effected by the solvent action of water impregnated with free carbonic acid. It is, in fact, not improbable that this removal of the carbonate of lime may proceed until what remains behind contains the two carbonates in the ratio of atom and atom, and be then arrested.

On the whole, then, I am disposed to conclude, that magnesian limestones, particularly such as contain organic remains, are generally original formations, and that if any of them are metamorphic rocks, that the alteration has been accomplished by the solvent action of aqueous carbonic acid upon calcareous strata, including also traces of carbonate of magnesia.

As an appropriate supplement to the preceding remarks, I shall now briefly draw the attention of the meeting to the analysis of another stone which was sent me also by Mr. Griffith, through the hands of our secretary, Mr. Hamilton. This stone, which was labelled "Chalk altered by contact with protruded trap from Ballygaun, County of Antrim," is of a dark speckled colour, and exhibits a somewhat shining aspect, and confused crystalline structure. Its specific gravity is 3.183.* When reduced to powder it effervesces slightly with muriatic acid, diluted with an equal volume of water; and, upon the application of a gentle heat, is dissolved, with the exception of a very minute quantity of dark particles, highly magnetic, and which would appear to be titonitic iron. The solution, when sufficiently concentrated, gelatinized; showing not only that silex was present, but that it had been in union with some base from which it was separated by the hydrochloric acid. Having fallen here upon an unquestionably metamorphic mineral, I became anxious of course to determine its exact composition, expecting that light would be thus thrown generally upon the nature of the action of the igneous upon the calcareous rocks.

With a view, therefore, to its analysis, 30 grains were reduced to a fine powder, and this was dissolved in nitro-muriatic acid with the application of heat. The solution was now evaporated to dryness, in order to render the silex insoluble, and the dry residue having been allowed to stand twelve hours moistened with strong muriatic acid, was then treated with distilled water, and the silex collected and well washed upon a double filter. After desiccation at a temperature of about 250°, it weighed upon the filter 14.5 grains. Of this 13.6 grains were exposed to a red heat in a platinum crucible, by which they were reduced to 9.2. Hence

13.6 : 9.2 : : 14.5 : 9.80, the

silex of the stone.

To the washings of the silex ammonia was added, which threw down a mixture of alumina and peroxide of iron, which, after having been collected and well washed on a single filter, was treated with caustic potash, by which the earth was dissolved. The peroxide of iron was now collected on a double filter, and, when well washed and dried, weighed 2 grains. Of these 1.9 grains were, by a red heat, reduced to 1.2. Hence

1.9 : 1.5 : : 2 : 1.45, the

true weight of the peroxide, which is equivalent to 1.32 grains of the protoxide of iron, the combination present in the stone.

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* Another fragment has the specific gravity of 3.227.

The alumina was next recovered from its solution in the potash by boiling with muriate of ammonia, and when collected in the usual manner, and dried at a moderate heat, weighed 1.9 grains. 1.5 grains were exposed to a strong red heat, and thus reduced to 1 grain. Hence

1.5 : 1 : : 1.9 : : 1.26, the

alumina in the mineral.

To the washings of the iron and alumen oxalate of ammonia was added in excess, by which the lime was thrown down in the form of oxalate. This, when collected on filters, washed, and dried at 220°, weighed 40.1 grains. By a low red heat 38 of these were reduced to carbonate of lime, which weighed 25.4 grains. Hence

38 : 25.4 : : 40.1 : 26.80, the

entire of the lime in the form of carbonate.

The washings of the oxalate of lime were next acidulated with sulphuric acid, and evaporated to dryness, a pretty strong heat having been finally applied, in order that the ammonical salts, and any excess of sulphuric acid employed be dissipated. The residue, which upon subsequent examination proved to be sulphate of magnesia, weighed 2.4 grains, which are equivalent to 0.81 of magnesia. The following, therefore, are the results of the analysis :—

Silex	9.80
Alumina	1.26
Protox. iron	1.32
Magnesia	0.81
Carbonate of lime ...	26.80
	39.99

The mineral being anhydrous, the 9.99 grains in excess obviously represent the carbonic acid of the lime present as a silicate, and the amount of which may be readily calculated to be 12.87 grains. And if we deduct 9.99+12.87=22 86 from 26.80, the residue, or 3.94 is the carbonate of lime which enters into the composition of the stone. The following is therefore the correct statement of the preceding analysis :—

	(1)	(2)	(3)	(4)
Silex	9.80	.210	.210	9.54
Alumina	1.26	.022	.022	1.00
Lime	12.87	.451	,526	2400
Magnesia	0.81	.039		
Protoxide of Iron	1.32	.036		
Carbonate of Lime	3.94			
	30.00			

In column (1) of the preceding table we have the experimental results. In column (2) the quotients got by dividing these by the atomic weights of the substances which they represent. In column (3) the same, only that those which belong to the isomorphous bases are added together. And in column (4) lower numbers in the same ratio with these.

The numbers in the last column show that, (leaving out of consideration the carbonate of lime, which is, of course, not chemically combined but mechanically intermixed with the silicates ;) there are 9.5 atoms of silica, 1 of alumina, and 24 of the mixed oxides of calcium, magnesium, and iron. Now, if we suppose the alumina present as a sesquisilicate, a not unusual state of combination for it to occur in ; there will be 8 atoms of silicic acid in combination with 24 atoms of mixed bases, or the stone under consideration will in the main be a mixture of trisilicates, or have a composition analagous to olivine.

Before making any observations on this very interesting and remarkable result, I shall adduce another analysis of the same stone performed in my laboratory by my friend Mr. Chance.

	(1)	(2)	(3)
Silex	9.21	,198	,198
Alumina	2.43	,047	,047
Lime	9.95	,349	,540
Magnesia	1.01	,048	
Oxide of Iron	5.15	,143	
Carbonate of Lime	2.25		

Here the constituents are the same, but the proportions are materially different, there being less lime, and more magnesia and oxide of iron. An inspection, however, of the numbers in column (3) shows that the formula is essentially the same, the only difference being that the alumina instead of being a sesquisilicate, is like the other basic oxides, present as a trisilicate. That this is the case will be obvious, if we divide 540+47=587 by 198, for the quotient will be found to be 2.96, or quam proximi 3.

That the chalk then at Ballygaun has been converted by contact with igneous rocks into an olivine, there can be no doubt, the only difference between the specimen under consideration and the purer varieties of this mineral being, that it contains a small quantity of silicate of alumina, and that in it the greater part of the magnesia is replaced by lime. Its specific gravity also, when we allow for the carbonate of lime mechanically present, corresponds with this conclusion, being, as has been stated 3.183, while that of grains of olivine was found by Stromeyer to be 3 338. The fact thus established appears to me generally interesting, and, in a geological point of view, important. By it we are enabled to understand why olivine should be so very frequently found in basalt, greenstone, and other trappean rocks, and to refer its origin to the contact of silex at a high temperature with an excess of the basic oxides. If the silex were redundant, augite not olivine would be formed. By it we have in some degree a demonstration that the dolomites which contain silicious sand, could not have been exposed at any time to a heat sufficiently high to account for the introduction into them of magnesia in the vaporous strata, for by such heat a silicate of lime, or magnesia, or of both would have been produced. And lastly, we have in the subject of our analysis, a striking instance of the tendency of nature to the production under the most unfavourable circumstances of definite compounds; and an unexpected illustration of those laws of isomorphous substitution, first announced by Mitscherlich, and which, notwithstanding the scepticism of some eminent chemists, I do not hesitate to consider as established upon foundations which cannot be shaken.

Since the preceding was written I have made the analysis of several other magnesian limestones, the result of which I subjoin here in the form of an appendix.

Cultra No. 1.

	(1)	(2)	(3)
Carbonate of Lime	16.73	.330	5
Carbonate of Magnesia and trace of Carbonate of Manganese	11.37	.265	4
Peroxide of Iron and Silex	1.47		
Water and Loss	1.43		

Cultra No. 2.

	(1)	(2)	(3)
Carbonate of Lime	17.81	.351	7
Carbonate of Magnesia and trace of Carbonate of Manganese	10.59	.247	5
Peroxide of Iron and Silex	0.76		
Water and Loss	0.84		
	30.00		

The numbers in column (1) are the experimental results, those in column (2) the quotients got by dividing the preceding by the atomic weights of the substances which they represent, and those in (3) the smallest integers which are either exactly or very nearly in the same ratio with those of column (2).

Specimens No. 1, has a light yellow or buff colour, a looser texture, and an arenaceous appearance. Its specific gravity is 2.559, and, neglecting the iron and silex, it is obviously composed of five atoms of carbonate of lime, associated with four of carbonate of magnesia, a little of the latter being replaced by carbonate of manganese.

Specimen No. 2, has a reddish brown colour, and a compact but not crystalline structure. It is translucent on the edges, and has a specific gravity represented by the number 2.715. Its composition is seven atoms carbonate of lime with five of carbonate of magnesia.

The preceding specimens are from Hollywood, on the coast of the County of Down, and were collected by my friend Dr. Andrews, professor of chemistry in the Belfast Institution. The geological structure of this district, and in particular the relations of the magnesian limestone to the surrounding rocks, are described by James Boyce, Esq. jun. in part 3, of this journal, page 175.

Kilgarvin, County Donegal.

	(1)	(2)	(3)
Carbonate of Lime	14.87	,323	1
Carbonate of Magnesia	12.80.	,328	1
Peroxide of Iron	0.84		
Silex	0.44		
Carbon and Loss	1.05		
	30.00		

This specimen has a dark blue colour, due to free carbon, and a close crystalline structure. Its composition is obviously an atom of carbonate of lime plus an atom of carbonate of *magnesia.* I have put down the iron as peroxide, but it is probably present as carbonate. For the following interesting facts, in reference to the geological relations of the Kilgarvin dolomite, I am indebted to Mr. Griffith:—

"Kilgarvin is situated on the western bank of Lough Swilly, in the County of Donegal, and one and a half miles north of Rathmullin. Here the dolomite forms part of a bed of primary limestone, usually of a bluish grey colour. At their western extremity the beds are cut off by large masses of crystalline greenstone, and near the contact with the greenstone the limestone becomes a dolomite. This is one among many similar examples in that neighbourhood."

From the County Derry.

	(1)	(2)	(3)
Carbonate of Lime	16.46	.325	1
Carbonate of Magnesia	11.47	.267	1
Carbonate of Iron	1.78	.050	
Silex and Loss	0.29		
	30.00		

This stone is very hard and compact, but has nothing of the crystalline structure. Its specific gravity is 2.766. To the eye it appears an aggregation of spherical masses of two distinct substances, the one having a brown and the other a perfectly white colour. The composition of both, however, is essentially the same; the only difference being that the brown contains most iron. I received this mineral from Professor Scouler, who found it labelled, in the handwriting of Sir Charles Giesecke, *Hydrocarbonate of Magnesia*. It is obviously a true dolomite, some of the magnesia being replaced by protoxide of iron.

Dodder.

	(1)	(2)	(3)
Carbonate of Lime	15.65	.309	1
Carbonate of Magnesia	11.46	.267	1
Carbonate of Iron and trace of Silex	2.55	.344	
Water and Loss	0.34		
	30.00		

This specimen, which has a blueish grey colour and crystalline structure, I picked up in the bed of the Dodder, near Miltown Bridge, where dolomite occurs imbedded in carboniferous limestone. It is worthy of being remarked here, that the contact of the limestone of the valley of Dublin with the granite to the south, occurs at many points along, and in the immediate vicinity of the Dodder.

OBSERVATIONS ON BEDS OF DOLOMITE, WHICH OCCUR IN CONNECTION WITH THE CARBONIFEROUS LIMESTONE, IN DIFFERENT PARTS OF IRELAND,

BY JOHN SCOULER, M. D. F. L. S.

PROFESSOR OF MINERALOGY TO THE ROYAL DUBLIN SOCIETY.

The history of magnesian limestones is still involved in much obscurity, and in many cases it is uncertain whether they have been originally deposited in the state in which we now find them, or are to be considered as portions of calcareous strata, which have subsequently been changed by the acquisition of carbonate of magnesia. In the dolomites which constitute detached portions of the carboniferous limestone, we find many evidences of their metamorphic nature, which render it extremely probable that the magnesia has been deposited at a period posterior to the formation of the limestones with which they are associated.

The dolomites of the carboniferous limestone are always local deposits; usually of very small extent, when compared with the great amount of country occupied by the ordinary limestone, and here their origin must be traced to local actions and chemical changes which were confined to a few detached points in the calcareous strata; that some of these dolomites were metamorphic is proved by the fact that they sometimes contain organic fossils of the same species as those which are found in the unaltered limestone. In the dolomite of Howth, in the vicinity of Dublin, specimens of Euomphalus pentangularis, and spirifers are sometimes found, and in such cases it is obvious that the substance of the shell has been changed from a simple carbonate of lime into a double carbonate of lime and magnesia. The circumstance that the dolomite passes, in many cases, into the ordinary limestone, by the most insensible gradation, favours the opinion, that a solution of carbonate of magnesia has penetrated the strata and infused itself through the porous limestone, in the same manner as a drop of water penetrates a piece of sugar. The subsequent origin of the dolomite is in some cases satisfactorily demonstrated by the circumstance that it forms veins which occupy fissures in the whimmer limestone, and include fragments of unaltered limestone.—Several examples of this form of dolomite occur at Howth, and also, as I am informed by Mr. Hamilton, in the County of Cork.

If we admit the metamorphic nature of the dolomites of the carboniferous limestone, in such cases it is apparent that we must seek for its cause, not in igneous action, but in the infiltration of waters charged with carbonate of magnesia. The theory of sublimation of magnesia from ignited rocks in the vicinity of limestone, even if we omit the chemical difficulties under which it labours, is totally inapplicable to the cases under consideration. Many of the dolomites of the carboniferous limestone occur at great distances from any igneous rock from which magnesia would be sublimed, and on the other hand, in the vicinity of Limerick, a pyroxenic trap has burst through the limestone in twenty different situations, and although, in some cases it has changed the calcareous rock into marble, yet, in no case has the contiguity of these igneous rocks given rise to the formation of a dolomite.

The metamorphosis of the carboniferous limestone into dolomite, may be more readily accounted for on the theory proposed by M. Virlet, of the infiltration of waters charged with carbonate of magnesia into the strata. This theory is exempt from the chemical difficulties which beset the theory of igneous sublimation. A water charged with carbonate of magnesia, would deposit that substance in the calcareous beds through which it flowed, while at the same time it would carry off a portion of carbonate of lime. Thus fulfilling all the conditions necessary for the formation of a dolomite, the abstraction of of lime, and the deposition of magnesia.

This theory is rendered still more probable from an examination of the relations of the beds of dolomite to the adjacent rocks. The dolomites in as far as they have come under my observation, occur in the following positions:—either in the vicinity of some igneous rock, as on the Dodder near Dublin, where a bed of dolomite occurs at the junction of the granite with the limestone, or at the junction of the limestone with some older rock, or near some fracture or dislocation of the strata, as in the case in the dolomites of Howth, Waterford, &c. The situations in which the dolomite occurs, are those in which Dr. Daubeny has proved that is most usual for mineral and thermal springs to be found, and consequently adds to the probability, that in many cases there were springs once existing in the places where dolomized limestone exists.

If the formations of certain dolomites can be satisfactorily explained by the theory of the infiltration of water charged with carbonate of magnesia, it becomes an interesting question to enquire from what source the magnesia could be supplied. We find that in many cases, especially the primary ones occur in the proximity of rocks which contain magnesia in considerable abundance. Magnesian limestones are found associated with trap rocks, talcose schists, and serpentines; and under such circumstances a water charged with carbonic acid flowing over a magnesian rock to a calcareous one, would change the latter into a dolamite. That carbonic acid is capable of dissolving magnesian rocks, has been proved by a very interesting observation mentioned by Mr. Fournet. In a case where a rock of steaschist had been exposed for a long time to the action of carbonic acid, it was found that every thing had been dissolved except the quartz. When we reflect on the common occurrence of carbonated waters in nature, and also that magnesia exists in the state of silicate in so many stratified derupted rocks, it is probable that it is to the solvent action of carbonic acid on magnesian rocks, that we must seek for the supply of magnesia, for many of the dolomites, either of the primary, secondary, or tertiary strata.

In many of the dolomites of the carboniferous limestone, we find that they are associated with oxides of iron and manganese, and this association is so frequent that the relation of the oxides of these two metals to the magnesian limestones cannot be considered an accidental one. The analyses of Berthier have proved that dolomites often contain carbonate of iron and sometimes even carbonate of magnesia, and that all the four carbonites may exist together, and still more frequently in a threefold combination of lime, iron, andmagnesia. It is known that when the oxides of iron and magnesia acquire an additional proportion of oxygen, their carbonic acid is set at liberty. In the case therefore of the dolomites of Howth, Waterford, &c., where oxide of manganese is also found in the same locality; or where oxide of iron occurs near the dolomite, the change of the ordinary limestone into a dolomite may be readily explained. If water be allowed access to any deposite of the carbonates of iron, manganese, lime, and magnesia, the two former pass into the state of peroxide while the carbonic acid dissolves the carbonates of lime and magnesia, which are afterwards deposited in the state of dolomite. It is to some change of this nature that we must attribute the origin of the mineral spring of St. Nectaire in Puy de Dome. According to Berthier this water contains the carbonate of soda, lime, and magnesia, with an excess of carbonic acid, and a considerable quantity of oxide of iron.—In such a case as this the excess of carbonic acid may be accounted for by the formation of the carbonate of iron, while the liberated acid gave solubility to the lime and magnesia. These circumstances are peculiarly applicable to the illustration of the formation of those beds of dolomite, which as is the case at Howth, are associated with exclusive deposits of oxides of iron and manganese.

A SHORT ACCOUNT OF LEAD MINES IN THE CO. CLARE.

BY P. M. TAYLOR, Esq.

MILLTOWN LEAD MINE.

The Miltown lead mine in the barony of Tulla, in the county of Clare, is probably one of the oldest mines in Ireland. At one time it may be supposed that there must have been a rich deposit, the ancient excavations being very extensive.

The Royal Irish Mining Company took a lease of it about twelve years ago, but after partially clearing the old workings, and driving a level for a short distance into the north side of the mine, they abandoned the speculation, after raising about eleven tons of ore.

In the year 1836, a grant of this mine was taken from the present proprietors, Anthony Colpoys and George O'Callaghan, Esqrs., by John Taylor, Esq. of London, whose name is so well known and deservedly identified with the mining interests of England.

The ancient workings were now completely cleared, and some rude tools discovered, such as oaken shovels and iron picks, the latter of an extraordinary size and weight; also the remains of fires which had been evidently made use of to crack and loosen the masses of calcareous spar and carbonate of lime, in which the ore of this mine is chiefly embedded. The spar is very beautiful, being perfectly white and much of it transparent.

After considerable labour and expense, Mr. Taylor's agents were disappointed in the expectations they had formed of making fresh discoveries of sufficient importance. The works therefore were abandoned in April 1838, after raising forty tons of ore which upon an average yielded about 75 per cent, of lead, and 37 oz. of silver for each ton of ditto.

Within half a mile of this mine upon the estate of James Moloney, Esq., of Kiltannon, are the celebrated Tomines, or immense natural vaulted passages of limestone, through which the river Ardsullas winds a most extraordinary course. The place is extremely curious, and the stupendous masses of rock forming a gigantic roof over the river, present a scene of magnificence which can never be forgotten by those who have viewed it.

The same river loses itself again among the cavernous strata of limestone rocks near Quin, and afterwards passing through the picturesque lake of Dromoland, falls into the Fergus, below Castle Fergus.

KILBRICKEN LEAD MINE, IN THE BARONY OF BUNRATTY AND PARISH OF DURA.

In the year 1833, attention was awakened by the circumstance of the accidental discovery of lead ore, by persons in his employment, on the estate of John M'Donnell, Esq., of New Hall, near Ennis.

The first specimens were found by persons while cutting the new line of road between Moriesk and the new town of Clare; after which more important discoveries were made on the farm of Moniuve by the tenant, John Egan, while cutting a drain through his bog.

The specimens and description of soil and calcareous spar in which these stones of ore were discovered, having been submitted to the inspection of Mr. Taylor, in London, he determined on sending agents to examine the district, and in consequence of their report, some experienced miners were despatched from England, through whose exertions about 25 tons of lead ore were raised and shipped, which sold at a very high price, being found to assay for lead 76 per cent, and for silver 120 oz. per ton.

At this time however the rush of water from the surrounding bogs was found to be an insuperable obstacle to further progress, without the aid of machinery, and it was then determined to stay the proceedings until a steam engine of sufficient power to contend against the difficulty, should be despatched from England. This engine was erected and put to work in 1837: operations are now going on upon an extensive scale, and great hopes are entertained of a successful result, but it is too soon to form an accurate opinion upon this point.

This mine is situated within 2½ miles of Quin, and is about six miles from Ennis.

BALLYHICKEY LEAD MINE, IN THE PARISH OF CLOONY AND BARONY OF BUNRATTY.

This is the richest lead mine which has been discovered in the County of Clare, and is upon the estate of Hugh Singleton, Esq. of Hazelwood: in a direct line of distance it is about 1½ mile east from Kilbricken, and here lead ore was discovered nearly at the surface. Operations were commenced by Mr. Taylor's agents in the autumn of 1834, and with decisive success, so much so that an export of 125 tons took place the following spring, and from that period to the present not less than 2500 tons have been shipped from the port of Clare to the river Dee, averaging by assay, 77 per cent for lead and 15 oz. for silver in the ton of lead, and a considerable quantity of ore is still raised and shipped monthly.

GEOLOGICAL REMARKS.

BY JOHN TAYLOR, Esq. OF COED DU.

The three deposits of ore above mentioned, occur in large veins of calcareous spar which traverse the limestone rock of this country; they differ from any hitherto observed in the mining districts of England and Wales, and indeed upon the continent of Europe. The veins of spar are of immense width; in places from 20 to 30 feet, and they run generally a little to the North of East and South of West.

The quantities of ore found at Milltown and at Kilbricken are so small, and the masses of spar so large, that it is not easy to trace the intersection of veins or branches at the points of deposit, as distinctly as at Ballyhicky. There the bunch of ore, the richest probably that was ever seen, taking the number of tons raised and the number of solid fathoms of ground broken into amount, occurs upon the intersection of two veins. The main vein runs N. E. and S. W., and its tributory falls in the angle of 45°. At this point the mass of ore was from 16 to 20 feet wide, in places, almost pure; in others, raised with sulphate of copper and zinc. The total length of the rich branch was about 40 feet, and it is still orey at the depth of 11 fathoms; how deep it may be worth pursuing is a question yet to be solved. The quantity of water is not considerable, although the mine is situated in the middle of a boggy piece of land. An engine, however, has been erected, for the double purpose of grinding the ores, and pumping the water. Fresh intersections of veins are still sought after, being the places at which only other deposits are expected.

END OF VOL. I.

REFERENCES TO THE SECTIONS ACCOMPANYING THE SECOND PART OF MR. TRIMMER'S PAPER.

SECTION IV.—TALARGOCH.

a—Limestone rock.
b—Lead vein.
c—Detrital deposit containing bones, shells, and pebbles of lead.

SECTION V.—CEFN CAVE.

a—Loam, with rolled pebbles, bones, and stalagmite, below *b*.
b—The level of the mouth of the cave.
c—Loam, with bones and angular fragments of limestone.
d—Sand, containing fragments of marine shells.
e—Limestone rock.

SECTION VI.—GWRYCH.

FIG. 1.

a—Loam, with a few pebbles.
b—Gravel.
c—Loam and gravel.
d—Osseous clay.
e—Limestone rock.

FIG. 2.

A transverse section of the wall of gravel, shewing that it has filled a fissure in the limestone rock *e*.

SECTION VII.—CRICCIETH CASTLE.

a—Quartz rock.
b—Ancient talus, consisting of angular fragments of the above.
c—A tongue, running from the talus into the deposit of loam and boulders.
d—Deposit of loam and boulders—no shells.
e—The remains of part of the ancient talus hanging on the rock, the loamy cliff having been cut back by the sea.

SECTION VIII.—ABERDARON BAY.

a—Rock, black slate at the base, chlorite slate towards the summit.
b—Collections of angular fragments of black slate.
c—Breccia *en place*, consisting of small angular detritus of black slate and chlorite slate cemented by a loamy base—no shells.
d—Loam and sand, with partially worn as well as angular boulders, and fragments of shells.

SECTION IX.—DINAS DINLLE.

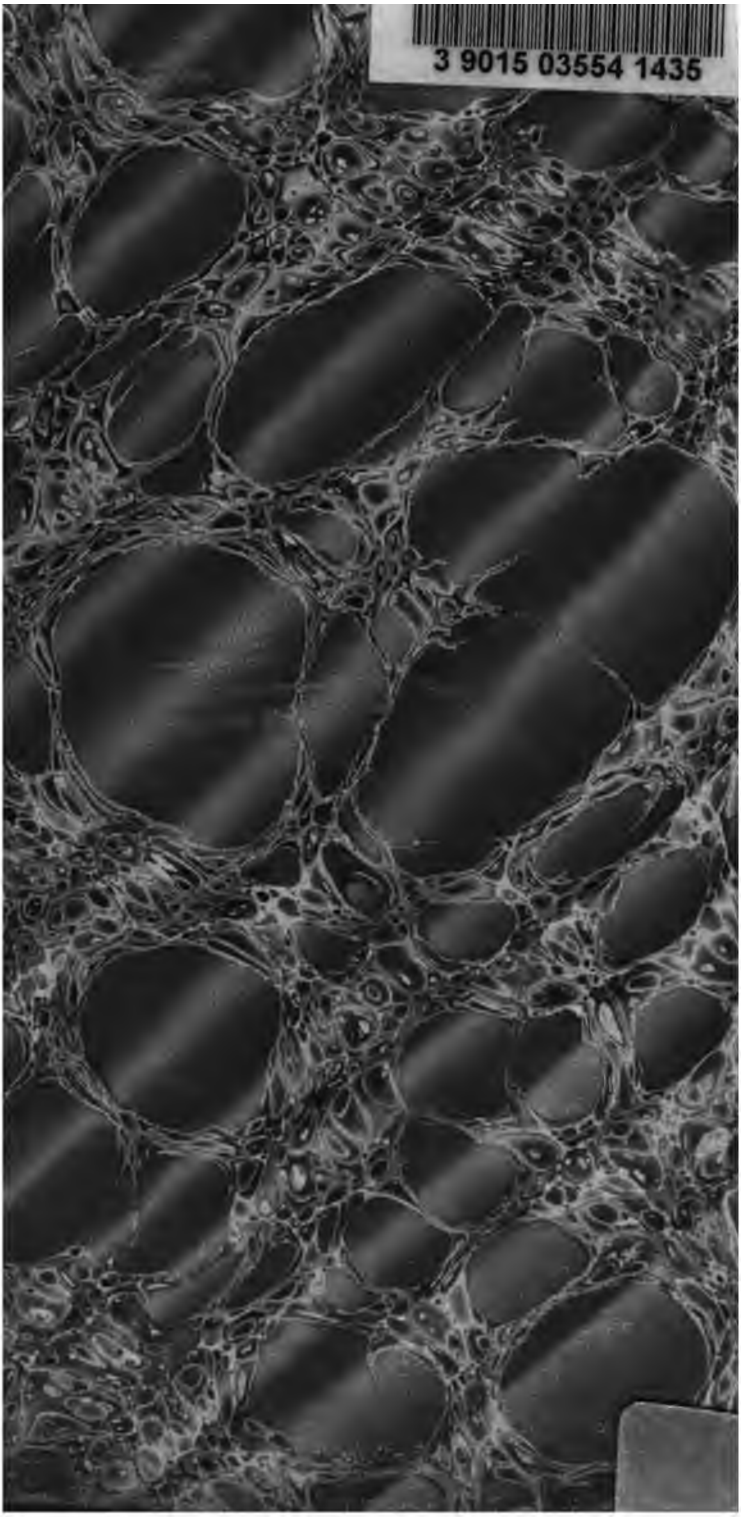
A—Gravelly loam.
B—Clay.
C—Fine gravel and sand; it contains some pebbles derived from the conglomerate of the Poikilitic series, and fragments of the violet roofing slate in great abundance.
D—Clay, very red towards the base of the cliff.
E—Very fine gravel, passing abruptly into coarse gravel in the upper part of the cliff.
F—Clay.
G—Coarse gravel, the pebbles much water-worn.
H—Silty loam, in some parts bluish, in others reddish.
I—Loam, with boulders and fragments of shells.
K—Coarse rounded gravel.
L—Clay.
M—Loam, with boulders and ftagments of shells.
N—Bluish clay, with irregular patches of gravel—fragments of shells.
O—Yellowish clay, with irregular patches of gravel.
P—Gravelly loam.
Q—An irregular bed of gravel.
R—Gravelly loam, with patches of gravel at T, and of sand at S.
V—Gravel.
W—Gravelly loam, with boulders—fragments of shells.
X—Gravel with a few boulders, six inches in diameter.
Y—Yellow sand and loam, with irregular patches of gravel, and a few boulders, twelve inches in diameter.

6

ERRATA

In Part I. of the paper on the Diluvial or Northern drift of the Eastern and Western sides of the Cambrian Chain.

Page 289, line 7, from the bottom, for "Juna," read "Jura."
—— 290, ——12, from the bottom, for "coast," read "east."
—— 295, —— 9, dele "it," and dele the period after "bed," in next line.
—— 297, ——24, for "granite," read "granite boulders."
—— —— ——30, for "one in an hundred affords," read "one in an hundred of which affords."
—— 302, —— 5, from the bottom, for "over the ridge from Stainmoor, &c." read "over the ridge. From Stainmoor, &c."
—— 303, —— 5, for "Garstary," read "Garstang."
—— 304, ——16, for "laid bare," read "laid dry."
—— —— —— 5, from bottom, for "position," read "portion."
—— 306, ——27, for "Straits of Menai," read "Straits of Malvern."
—— —— —— 7, from bottom, for "tertiary," read "tertiary formations."
—— 309, —— 1, for "any," read "my."
—— 310, ——11, from the bottom, for "requires," read "require."
—— 312, ——23, for "elevations," read "elevation."



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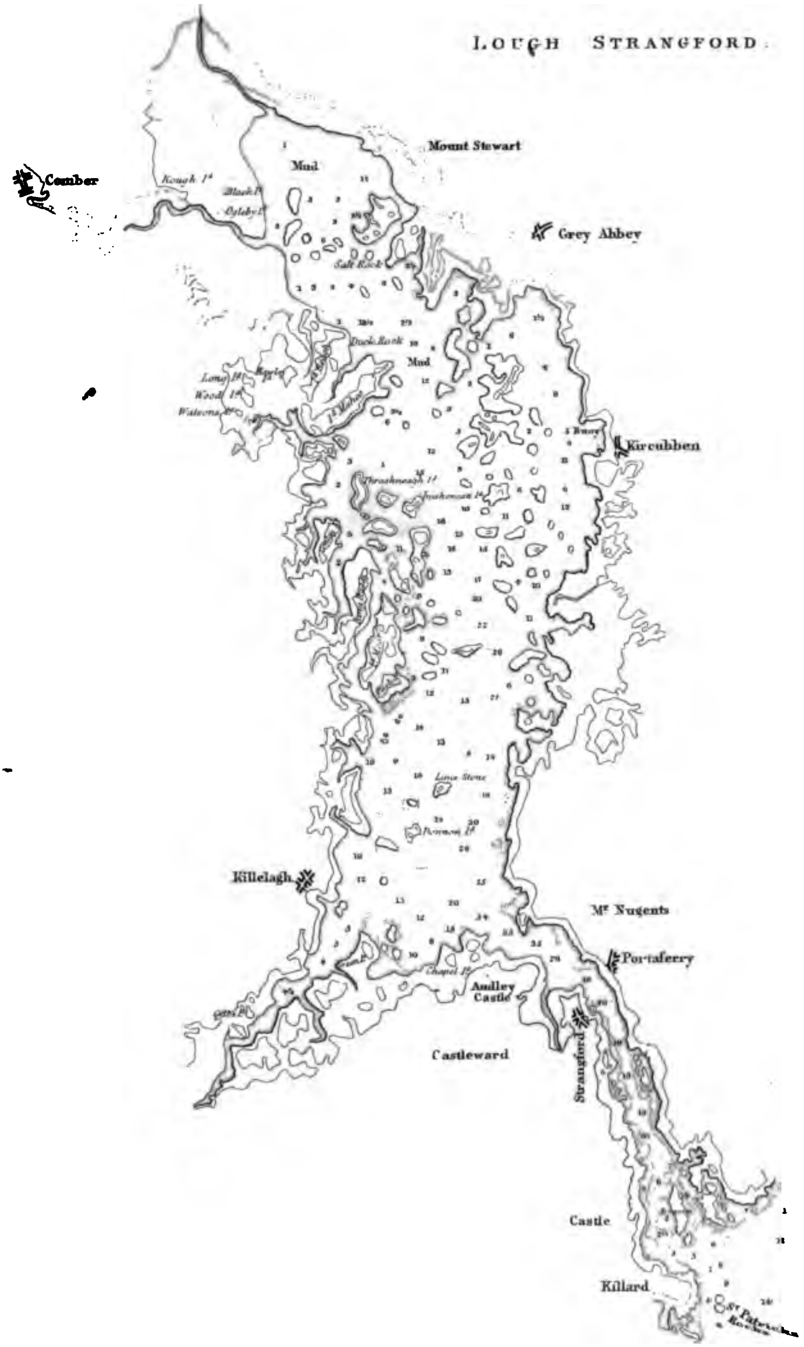
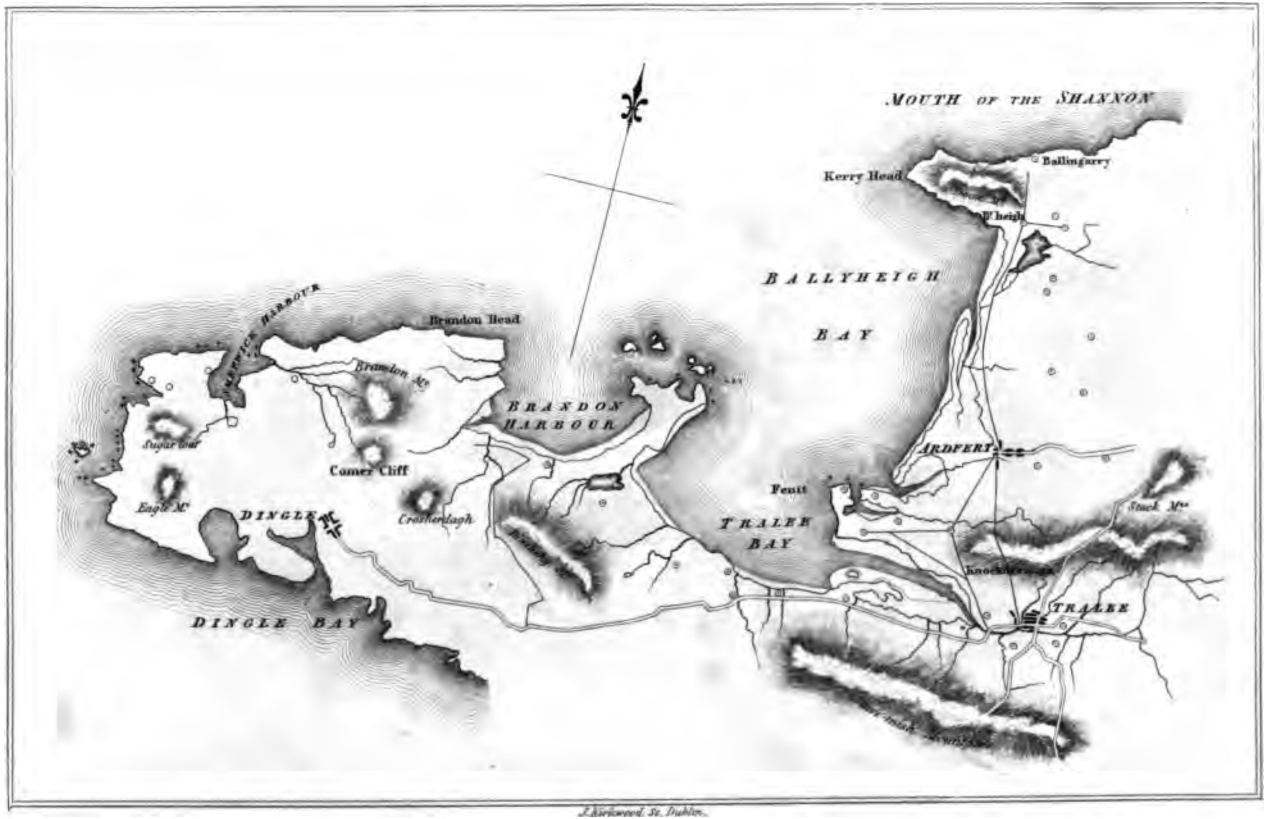
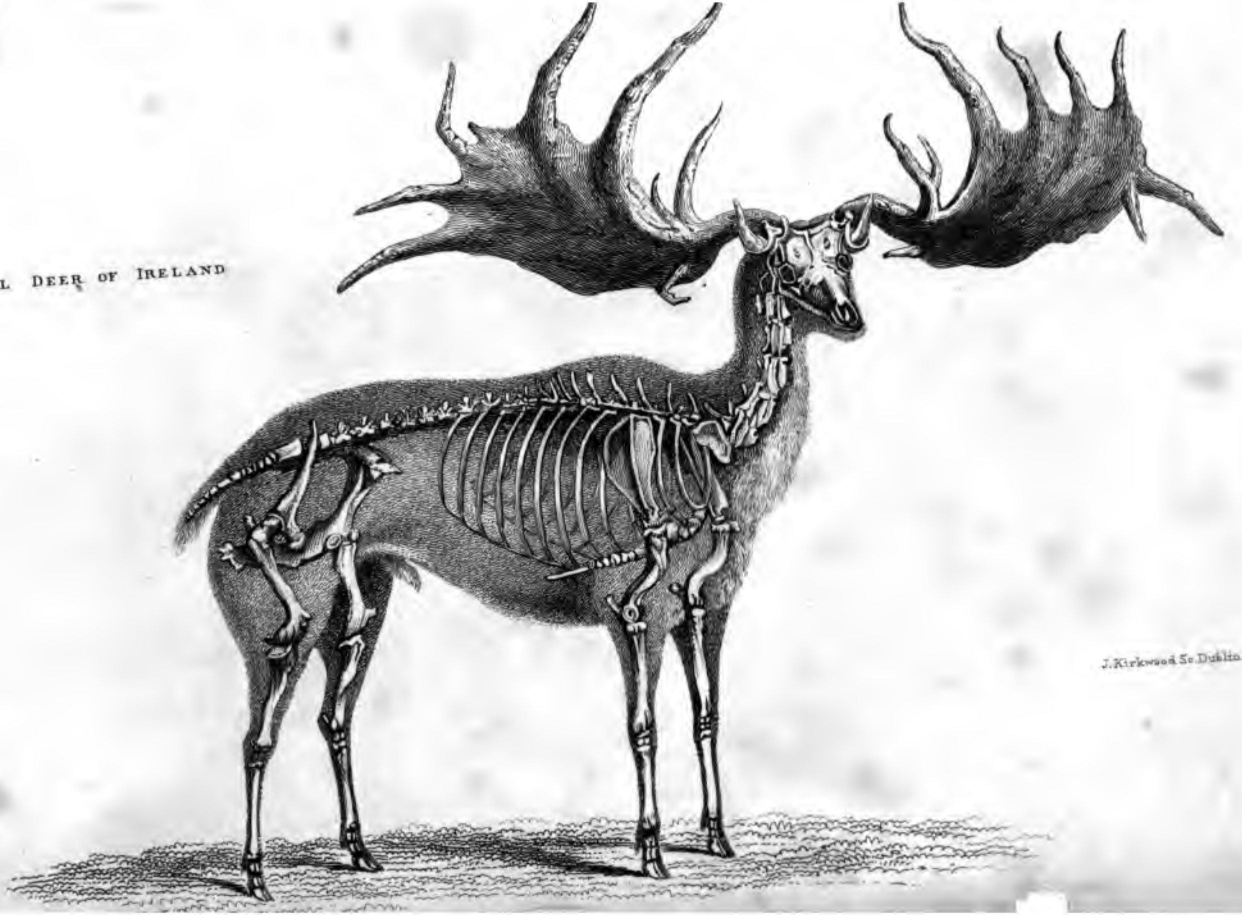

LOUGH STRANGFORD.

J.Kirkwood Sc Dublin



J. Kirkwood Sc. Dublin.



FOSSIL DEER OF IRELAND

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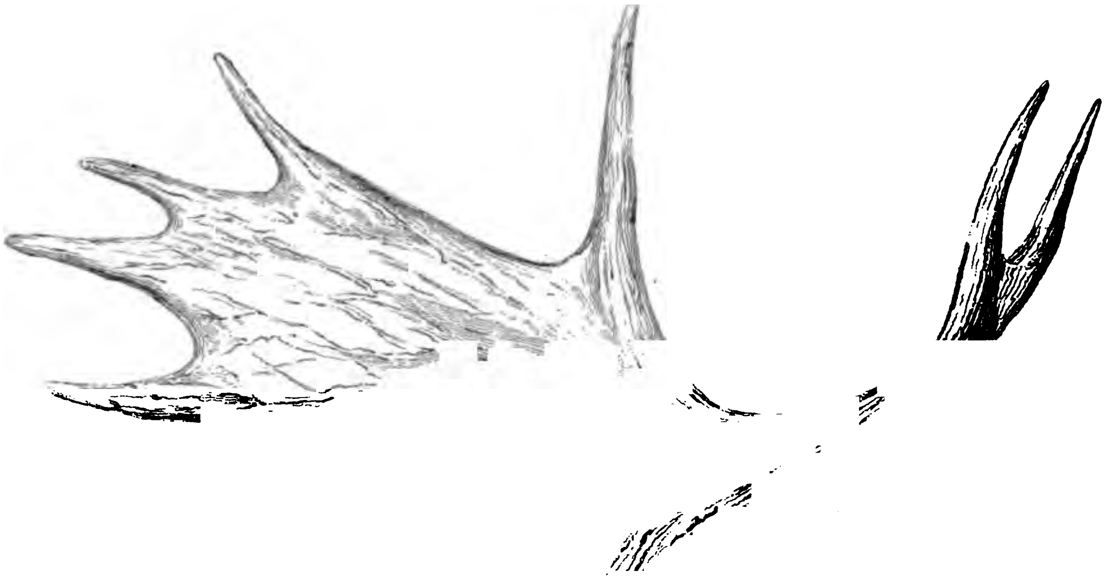
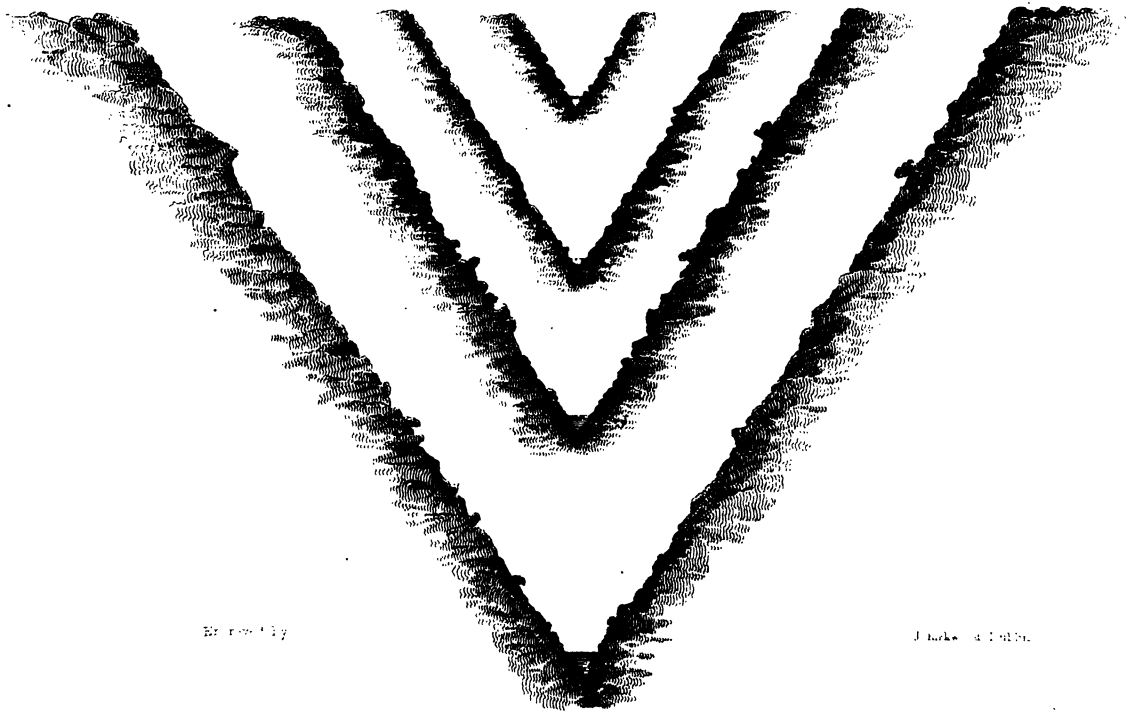


ANTLER OF THE CANADIAN ELK.

J Kirkwood Sc. Dublin

Vallies forming in loose Strata by preserving similarity of Slope.



Engraved by

[illegible]

FIG

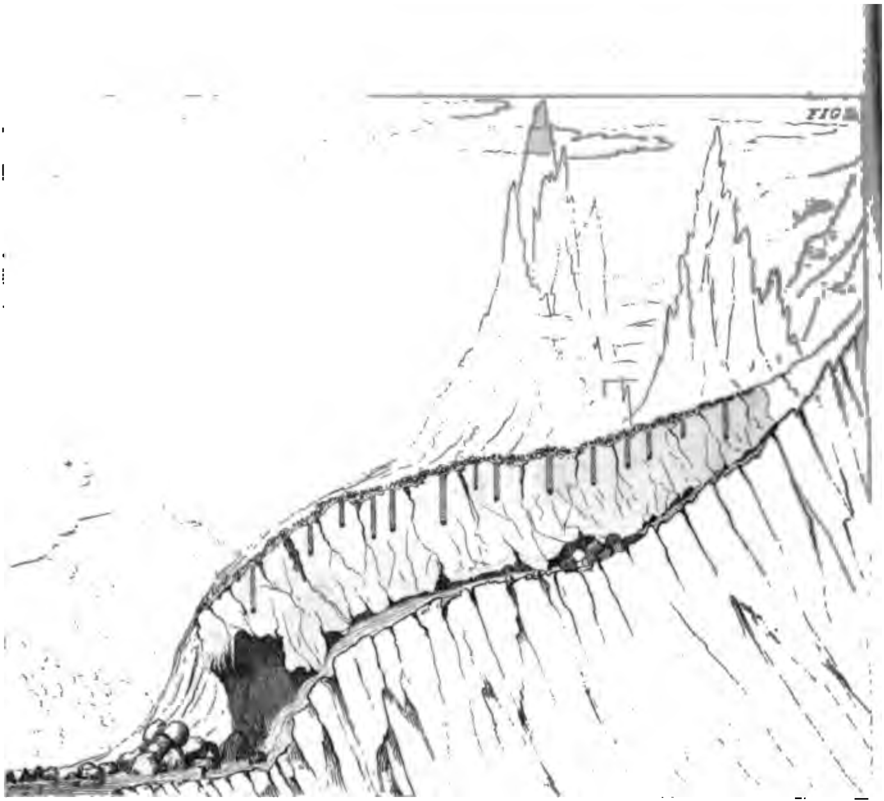
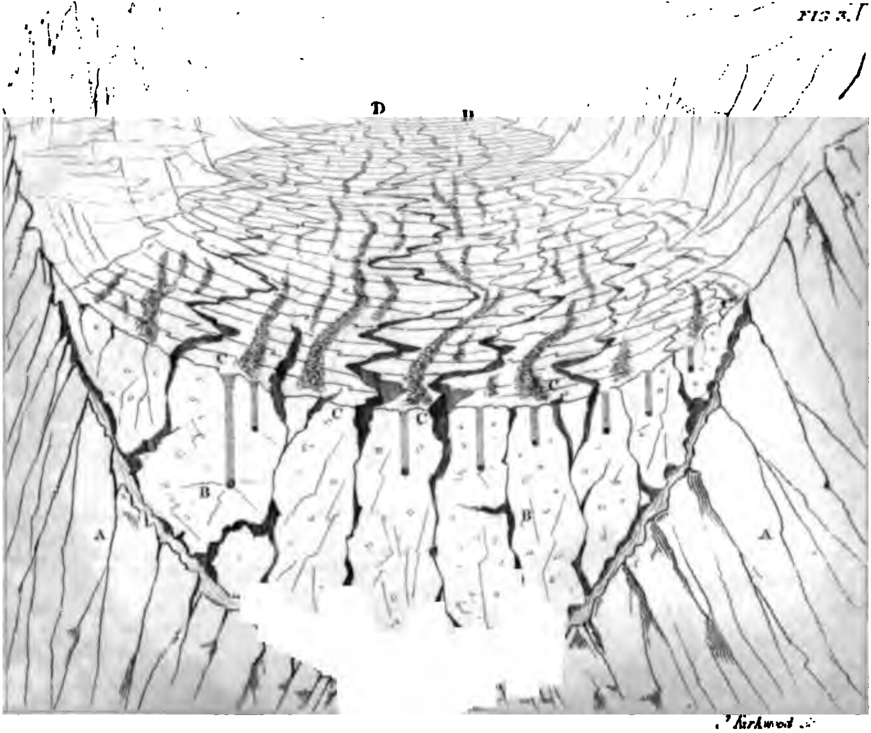


FIG 3.



Kirkwood sc.

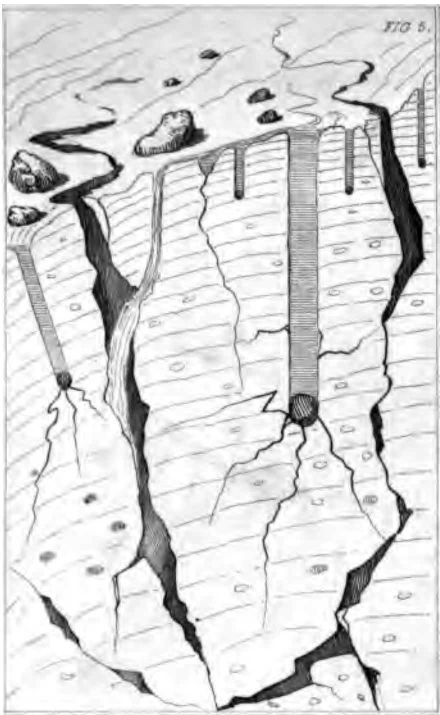


FIG 5.

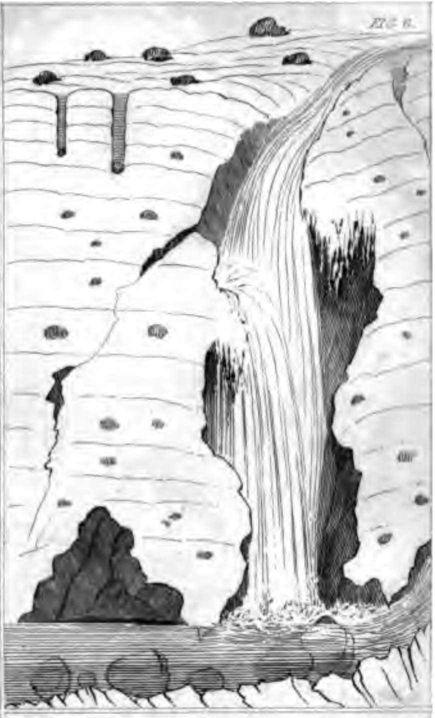


FIG 6.

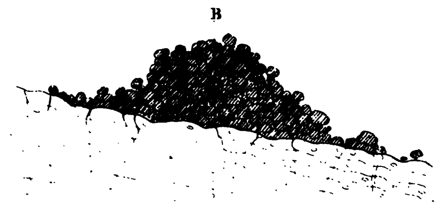


FIG 11.

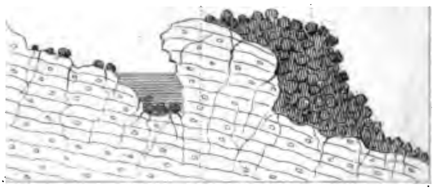


FIG 14.

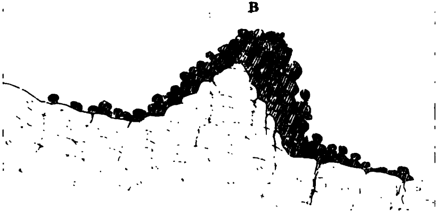


FIG 12.

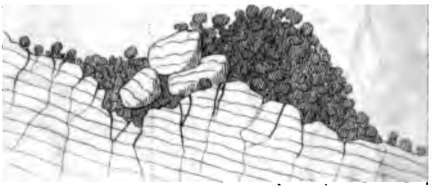


FIG 15.

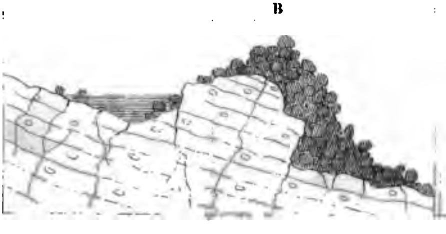
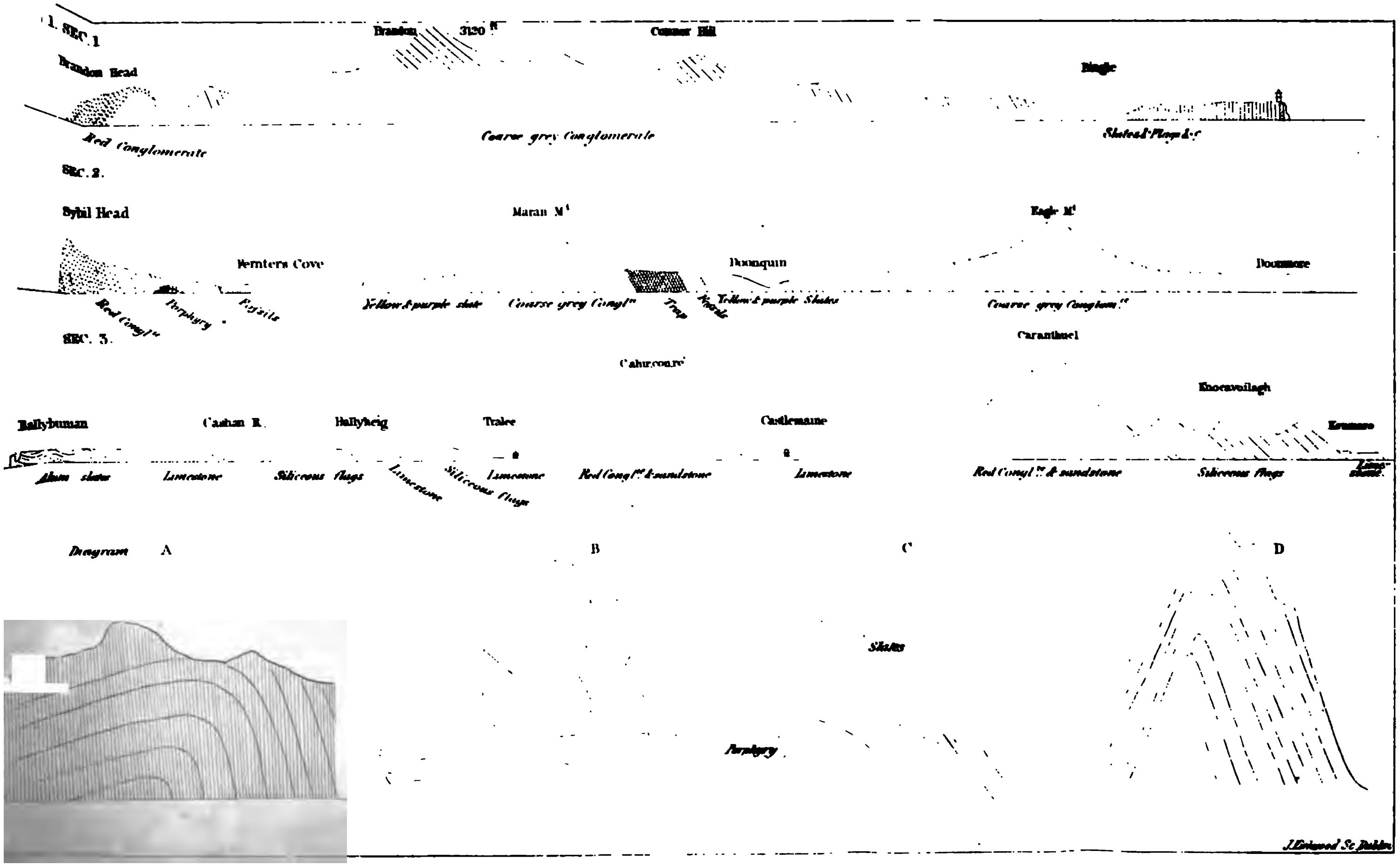


FIG 13.

A Centre of the base on which the moraine first rests.

B Constant centre of the mass of the moraine or vertical line passing through centre of gravity of its cross section

The horizontal interval between A and B shews the amount of lateral transfer of the moraine.


1.
SEC. 1
Brandon Head
Brandon 3120 ft
Connor Hill
Dingle
Red Conglomerate
Coarse grey Conglomerate
Slates & Flags &c
SEC. 2.
Sybil Head
Ferriters Cove
Maran Mt
Dunquin
Eagle Mt
Doonmore
Red Conglte
Porphyry
Fossils
Yellow & purple slate
Coarse grey Conglte
Trap
Yellow & purple Slates
Coarse grey Conglomte
SEC. 3.
Caranthuel
Cahirconre
Knocavoilagh
Ballybunian
Cashan R.
Ballyheig
Tralee
Castlemaine
Kenmare
Alum slate
Limestone
Siliceous flags
Limestone
Siliceous flags
Limestone
Red Conglte & sandstone
Limestone
Red Conglte & sandstone
Siliceous flags
Limestone
Diagram A
B
C
D
Slates
Porphyry
J. Kirkwood Sc. Dublin